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CARNEGIE INSTITUTION

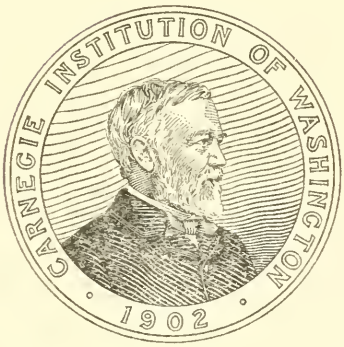
OF

WASHINGTON

YEAR BOOK

No. 7

1908



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ROBERT S. WOODWARD

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ELIHU ROOT, *Vice-Chairman*
CLEVELAND H. DODGE, *Secretary*

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*ROBERT S. WOODWARD

Finance Committee

D. O. MILLS
HENRY L. HIGGINSON
SETH LOW

* Ex-officio member.

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ARTICLES OF INCORPORATION.

The Carnegie Institution was originally organized under the law governing the organization of corporations in the District of Columbia. Owing to certain limitations in the law, the Trustees deemed it desirable to obtain articles of incorporation from the Congress. Accordingly, articles of incorporation were prepared, submitted to the Congress, amended by the Congress, and enacted into statute by the Congress and the signature of the President.

Organization under the new articles of incorporation was effected on May 18, 1904. Resolutions were passed electing the same Executive Committee and officers as those of the Carnegie Institution organized in 1902 and continuing all instructions and authorizations given to the Executive Committee by the old organization.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time

to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt bylaws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause

existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. No person shall be elected, however, who shall not have been nominated at a preceding annual or special meeting, except by the unanimous consent of the members present at a meeting.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the second Tuesday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the

Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized. He shall have custody of the seal of the corporation and shall affix the same whenever authorized to do so by the Board of Trustees or by the Executive Committee or the Finance Committee.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of all property of the Institution whose custody is not otherwise provided for. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz, an Executive Committee and a Finance Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have general charge of the investments and funds of the corporation, and shall care for and dispose of the same subject to the directions of the Board and of the Executive Committee. It shall consider and recommend to the Board of Trustees such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting.

8. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by

a skilled accountant, to be appointed by the Chairman of the Board, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property shall be deposited in such safe deposit or other corporation and under such safeguards as the Trustees and Executive Committee shall designate; and the moneys of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

Sixth Meeting of the Board of Trustees

DECEMBER 8, 1908

ABSTRACT OF THE MINUTES OF THE SIXTH MEETING OF THE BOARD OF TRUSTEES.

The meeting was held in Washington, at the New Willard Hotel, on Tuesday, December 8, 1908, and was called to order at 10 o'clock a. m., by the chairman, Mr. Billings.

Upon roll-call by the Secretary, the following members responded: John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Henry L. Higginson, Charles L. Hutchinson, Seth Low, S. Weir Mitchell, Andrew J. Montague, William B. Parsons, Henry S. Pritchett, Charles D. Walcott, William H. Welch, Andrew D. White, Robert S. Woodward, and Carroll D. Wright.

Mr. Andrew Carnegie, the founder of the Institution, was also present during a part of the meeting.

Absent: E. A. Hitchcock, William Lindsay, D. O. Mills, William W. Morrow, Elihu Root, William H. Taft.

The minutes of the fifth meeting were approved as printed in abstract and submitted to the Trustees.

The reports of the President, the Executive Committee, the auditor, the Finance Committee, of directors of departments, and of grantees of the Institution, were presented and considered.

After explanation and discussion, the following general appropriations were made for 1909:

Publication	$50,000
Administration	50,000
Grants for departments and large projects	435,500
Minor grants and research associates	75,800
For beginning work of republication of the Classics of International Law	10,000
Insurance Fund	15,000
	$636,300

The resignation of Mr. Carroll D. Wright as a Trustee was presented and accepted with regret.

Dr. Charles W. Eliot, of Cambridge, Massachusettts, and Mr. Martin A. Ryerson, of Chicago, Illinois, were unanimously elected to fill the vacancies in the Board caused by the death of Mr. Gilman and the resignation of Mr. Wright.

Messrs. Root and Walcott were elected members of the Executive Committee to succeed themselves for a term of three years.

Messrs. Parsons and Welch were elected members of the Executive Committee to succeed Messrs. Gilman and Wright for the unexpired term ending in 1909.

Mr. Welch was appointed to prepare a suitable minute regarding the death of Mr. Gilman.

The Board adjourned at 1:15 p. m.

Memorial

Daniel Coit Gilman

1831–1908

The Trustees of the Carnegie Institution of Washington direct that the following Minute be made in the permanent records of the Institution:

Daniel Coit Gilman, one of the original incorporators and the first President of the Institution, from the beginning a Trustee and a member of the Executive Committee, died in Norwich, Connecticut, October 13, 1908, in the seventy-eighth year of his age.

The central achievement of Mr. Gilman's life in the organization and development of the Johns Hopkins University during the quarter-century of his presidency marks an era in the history of higher education and productive scholarship in America. In this epoch-making work Mr. Gilman manifested largeness of conception, high administrative capacity, sound and discriminating judgment in the choice of teachers, wide and varied intellectual interests, sympathy with the sciences both of nature and of humanity, resourcefulness and steadfastness of purpose, and loyalty of character.

In addition to his activities in the cause of higher education, Mr. Gilman rendered efficient service as a member of the Venezuelan Boundary Commission and as president of the National Civil Service Reform League, of the American Oriental Society, and of the American Bible Society, and he took an active part in the administration of the Peabody Fund, the Slater Fund, the General Education Fund, and the Russell Sage Foundation. Before coming to the Johns Hopkins University he had been professor of physical and political geography at Yale and president of the

University of California. As evidences of his activity as a public-spirited citizen in the community where he lived may be mentioned his formation of the Charity Organization Society and of the Municipal Art Society in Baltimore, and his services as a member of the New Charter Commission and as a Commissioner of Public Schools in that city.

Retiring in 1901, at the age of seventy, after twenty-five years of service, from the presidency of the Johns Hopkins University, Mr. Gilman in January, 1902, became one of the incorporators and the President of the Carnegie Institution of Washington, as well as chairman of its Executive Committee. Resigning the presidency in December, 1904, he continued to serve the Institution as Trustee and member of the Executive Committee until his death.

To his trusteeship and the presidency of the Carnegie Institution of Washington, Mr. Gilman brought the prestige of a name long identified with the advancement of the interests of higher education and sound learning. In cooperation with his associates in the Board of Trustees, he entered upon an arduous task in an unexplored field with enthusiasm, devotion, and energy, in full sympathy with the far-reaching conceptions of the founder, with discernment of the novel and great opportunities presented, and in a spirit of open-minded, conscientious study of the new problems, securing at home and abroad the advice and aid of scientific authorities. Under his administration the new Institution was successfully launched upon broad lines of policy and attained, even in this early formative period, a position of large usefulness and importance.

With grateful appreciation of Mr. Gilman's services to the Institution, the Trustees express their sorrow in the loss of an honored associate whose life was full of good works and large in achievement.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

REPORT OF THE PRESIDENT OF THE INSTITUTION

In compliance with the provisions of Article IV of the By-Laws of the Carnegie Institution of Washington, I have the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1908, along with recommendations of appropriations for the ensuing year and with sundry suggestions and recommendations concerning other questions which have been under consideration during the past year.

Explanatory Statement.

This report is the seventh annual report of the Institution and is presented under the following heads:

1. Work of administration.
2. Résumé of work of year.
3. Publications.
4. Recommendation of budget for the year 1909.*
5. New projects.*

During the preparation of this report the world of learning has been apprized of the death, on October 13, at Norwich, Connecticut, of Dr. Daniel Coit Gilman, first President of the Institution and a member of the Executive Committee since its organization, in 1902. Dr. Gilman had attained the age of seventy-seven years, and he was apparently in full possession of mental and bodily vigor when death came suddenly and painlessly. His remarkable career as President of the University of California, of Johns Hopkins University, and of the Carnegie Institution of Washington, and as a trustee of many educational and philanthropic corporations, is too well known to be recounted here. His rare achievement in the development of Johns Hopkins University, as an educational organization devoted mainly to research, paved the way undoubtedly to the successful development of the Carnegie Institution of Washington as an organization devoted exclusively to research. He was deeply interested in all efforts for the advancement of knowledge and for the improvement of educational and social conditions. He was especially interested in the progress of the work of the Institution, while his confident optimism and his kindly counsel have

*It has been deemed unnecessary to print these sections of the President's report in the Year Book.

been a source of unfailing encouragement to those of his colleagues who have had access to his more intimate friendship since his retirement from the presidency.

WORK OF ADMINISTRATION.

In order to indicate the growth and the extent of the work thus far undertaken and accomplished by the Institution, the salient facts and figures are here condensed into a single paragraph. Since its organization, in 1902, about 1,000 individuals have been engaged in investigations under the auspices of the Institution and there are at present nearly 500 so engaged. Ten independent departments of research, each with its staff of investigators and assistants, have been established. In addition to these larger departments of work, organized by the Institution itself, numerous special researches, carried on by individuals, have been subsidized. Six laboratories, for as many different fields of investigation and in widely separated localities, have been constructed and equipped. A building in Washington, D. C., for administrative offices and for storage of records and publications, is half completed. The plans and specifications for the construction of a specially designed ship for ocean magnetic work have been recently completed, and a temporary observatory for supplementary measures of the positions of the fixed stars of the southern hemisphere is now being established at San Luis, Argentina. Work in almost every field of research, from archeology and astronomy to thermodynamics and zoology, has been undertaken, and the geographical range of this work has extended to more than thirty different countries. One hundred and twenty volumes of researches, in nineteen different fields of research, with an aggregate of more than 30,000 pages, have been published, and 27 volumes of researches are now in press. In addition to these publications issued by the Institution, about 1,000 shorter papers have been published in the current journals of the world by departmental investigators, by associates, and by assistants. The total amount of funds appropriated for expenditure to date is $3,683,840.00, which includes $293,928.37 reverted and afterwards reappropriated. The total amount expended to date is $3,359,236.17.

Summary of Work of Institution to Date.

It is a pleasant duty to make record here of an addition of $2,000,000 to the endowment of the Institution, tendered by the founder in a letter addressed to the President December 4, 1907. This gift was formally accepted by the Board of Trustees at their meeting of December 10, 1907. The securities of this addition bear interest at the same rate as the securities of the original endowment, but interest falls due for the former in January and July instead

Addition to Endowment.

of in February and August for the latter. The increase in the income of the Institution during the past fiscal year was, therefore, only $50,000. This was made available by the Trustees for allotment by the Executive Committee.

Financial Statement for the Fiscal Year 1907-1908.

The sources of funds available for expenditure during the past year, the allotments for the year, and the balances unallotted at the end of the year are shown in detail in the following tabular statement:

	Unallotted Oct. 31, 1907.	Appropriation, Dec. 10, 1907.	Revertments, Oct. 31, 1907, to Oct. 31, 1908.	Total.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1908.
Large Grants	$27,907.22	$417,440	$2,000.00	$447,347.22	$419,847.22	$27,500.00
Minor Grants	.....	47,500	4,824.00	52,324.00	52,324.00	.....
Research associates and assistants	.....	15,000	3,666.33	18,666.33	18,666.33	.....
Publications	16,635.62	50,000	7,830.53	74,466.15	59,768.14	14,698.01
Administration	10,870.35	50,000	.....	60,870.35	48,254.65	12,615.70
Total	55,413.19	579,940	18,320.86	653,674.05	598,860.34	54,813.71

The following list shows the departments of investigation to which the larger grants were made by the Trustees and the amounts allotted from those grants by the Executive Committee during the year:

Department of Botanical Research	$29,240.00
Department of Economics and Sociology	30,000.00
Department of Experimental Evolution	28,200.00
Department of Historical Research	20,000.00
Department of Marine Biology	13,000.00
Department of Meridian Astrometry	20,000.00
Department of Terrestrial Magnetism	57,000.00
Department of Terrestrial Magnetism, vessel	40,000.00
Geophysical Laboratory	42,000.00
Horticultural Work of Luther Burbank	10,000.00
Nutrition Laboratory	35,000.00
Solar Observatory	85,000.00
	409,440.00
Transferred to research associates and assistants by Executive Committee, April 21, 1908	407.22
Unallotted balance transferred to unappropriated fund	10,000.00
	419,847.22

The fields of investigation to which minor grants were assigned, the names of the grantees, and the amounts of the grants are shown in the first list on the following page.

Details of minor grants.

Field of investigation.	Names of grantees.	Amounts of grants.
Archeology	American School of Classical Studies at Athens	$2,500.00
	American School of Classical Studies in Rome	1,600.00
Astronomy	Campbell, W. W.	4,000.00
	Newcomb, Simon	5,000.00
Bibliography	Index Medicus	12,500.00
Chemistry	Acree, S. F.	500.00
	Jones, H. C.	800.00
	Morse, H. N.	1,800.00
	Noyes, A. A.	3,000.00
Engineering	Goss, W. F. M.	3,000.00
Geology	California State Earthquake Investigation Commission	140.89
Geophysics	Adams, F. D.	1,500.00
Literature	Sommer, H. O.	2,000.00
Metallurgy	Howe, Henry M.	300.00
Meteorology	Bjerknes and Sandström	1,200.00
Paleontology	Wieland, G. R.	2,000.00
Physics	Barus, Carl	500.00
Physiology	Reichert, E. T., and Brown, A. P.	1,000.00
Zoology	Castle and Mark	500.00
	Naples Zoological Station	1,000.00
	Mark, E. L.	300.00
		45,140.89
Transferred to research assistants and associates by Executive Committee, April 21, 1908		3,259.11
Transferred to Large Grants by Executive Committee, May 28, 1908		2,000.00
Unallotted balance transferred to unappropriated fund		1,924.00
		52,324.00

The following table shows the fields of investigation, the names of research associates, and the amounts of their grants:

Field of investigation.	Names of research assistants and associates.	Amounts of grants.
Astronomy	Kapteyn, J. C.	$1,800.00
	Nichols, Ernest F.	1,000.00
Chemistry	Richards, Theodore W.	2,500.00
Economics	Rowe, L. S.	1,500.00
Geophysics	Ludwig, Albert	1,500.00
History	Fish, Carl R.	2,800.00
Nutrition	Osborne, Thomas B.	4,000.00
Physiology	Loeb, Leo	500.00
Terrestrial Magnetism	Beattie, J. C.	2,500.00
Zoology	Gudger, Eugene W.	300.00
		18,400.00
Unallotted balance transferred to unappropriated fund by Executive Committee, October 13, 1908		266.33
		18,666.33

The following grants for publication were authorized during the year:

Barus, Carl	$1,500.00
California State Earthquake Investigation Commission	4,500.00
Cannon, W. A., and A. A. Knox	975.00
Chamberlin, R. T.	600.00
Chamberlin, T. C., *et al.*	600.00
Coblentz, W. W.	750.00
Davenport, C. B.	44.20
Eigenmann, C. H.	5,000.00
Index to Public State Documents	5,000.00
Jones, H. C., and J. A. Anderson	2,200.00
Lehmer, D. N.	6,400.00
Lutz, Frank E.	600.00
MacDougal, D. T., *et al.*	$2,500.00
Mayer, A. G.	7,000.00
Papers of the Marine Biological Laboratory	5,085.00
Putnam, Herbert	1,413.94
Shull, G. H.	800.00
Sommer, H. O.	6,000.00
Spalding, V. M.	2,400.00
Van Deman, Esther B.	700.00
Ward, W. H.	5,500.00
Wieland, G. R.	200.00
	59,768.14

The sources and amounts of the revertments from November 1, 1907, to October 31, 1908, inclusive, are as follows:

Transferred to Large Grants:		
Minor Grants		$2,000.00
Transferred to Minor Grants:		
Howe, W. Wirt, Grant No. 199	$900.00	
Goss, W. F. M., Grant No. 488	1,500.00	
Carnegie Institution of Washington, Grant No. 457	500.00	
Eames, Wilberforce, Grant No. 343	924.00	
Index Medicus, Grant No. 484	100.00	
		4,824.00
Transferred to Research Associates and Assistants:		
Large Grants	407.22	
Minor Grants (new)	2,059.11	
Minor Grants (previously implied)	1,200.00	
		3,666.33
Transferred to Publication fund:		
Benedict, F. G., Grant No. 436	609.89	
Conard, H. S., Grant No. 472	308.12	
Durand, W. F., Grant No. 446	216.48	
Goss, W. F. M., Grant No. 385	350.79	
Guide to the Archives of the Government at Washington, Grant No. 465	529.32	
Hodell, C. W., Grant No. 459	676.38	
Lloyd, F. E., Grant No. 448	808.19	
Lutz, F. E., Grant No. 513	322.83	
MacDougal, D. T., Grant No. 449	817.25	
MacDougal, D. T., Grant No. 509	1,197.50	
Peters, C. H. F., Grant No. 130	1,782.30	
Shaw, J. B., Grant No. 437	36.87	
Shepherd, W. R., Grant No. 463	55.61	
Willis, Bailey, Grant No. 454	119.00	
		7,830.53
		18,320.86

Summary of Receipts and Expenditures of the Institution to Date.

The aggregate receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refund on grants and miscellaneous items to date is $3,515,069.54, as shown by the following table:

Year ending Oct. 31—	Interest.		Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
	Endowment.	Bonds and bank deposits.				
1902.....	$250,000.00	$9.70	.....	.....	$1,825.52	$251,835.22
1903.....	500,000.00	5,867.10	$2,286.16	.....	101.57	508,254.83
1904.....	500,000.00	33,004.26	2,436.07	$329.33	669.70	536,439.36
1905.....	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906.....	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907.....	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908.....	550,000.00	17,761.55	7,877.51	25.68	*48,034.14	623,698.88
	3,300,000.00	132,579.72	26,014.47	5,659.76	50,815.59	3,515,069.54

* Includes $48,000 received from sale of bond.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads, namely: (1) investments in bonds and on account of Administration Building; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The actual expenditures under these heads for each year since the foundation of the Institution are shown in the following table:

Year ending Oct. 31—	Investments in bonds and on account of administration building.	Large projects.	Minor projects, special projects, research associates and assistants.	Publications.	Administration.	Total.
1902....	.....	.....	$4,500.00	.....	$27,513.00	$32,013.00
1903....	$100,475.00	.....	137,564.17	$938.53	43,627.66	282,605.36
1904....	196,159.72*	$19,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905....	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906....	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907....	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908....	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
Total..	481,797.11	1,650,714.85	753,925.96	190,579.48	282,218.77	3,359,236.17

* This amount includes an investment of $94,722.22 of the surplus cash account in bonds as follows:
$50,000 Northern Pacific-Great Northern 4 per cent joint bonds, Chicago, Burlington and Quincy collateral, July, 1921.
$50,000 Lake Shore and Michigan Southern Railway 4 per cent debenture bonds.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipment of departmental establishments, the following sums have been expended:

Table Showing Expenditures on Account of Site for and Construction of Administration Building, Real Estate, etc.

Administration:		
Building and site (chargeable to Administration Building fund)	$133,224.89	
Furniture on hand	4,437.63	
		$137,662.52
Department of Botanical Research (inventory to July 30, 1908):		
Office and library	3,812.18	
Apparatus	5,508.15	
Buildings	15,089.25	
Grounds, fencing, and water supply	5,154.98	
		29,564.56
Department of Experimental Evolution (inventory to Sept. 30, 1908):		
Office and library	4,928.18	
Laboratory	2,523.44	
Buildings	29,610.95	
Field appliances	4,339.20	
		41,401.77
Geophysical Laboratory (inventory to Sept. 30, 1908):		
Office and library	6,954.98	
Laboratory	50,959.24	
Shop	10,115.62	
Building and site	99,606.00	
		167,635.84
Department of Marine Biology (inventory to Sept. 30, 1908):		
Vessels	10,360.66	
Buildings and docks	7,615.24	
Apparatus	900.39	
Furniture and library	1,136.80	
		20,013.09
Solar Observatory (inventory to Sept. 30, 1908):		
Buildings, grounds, road, telephone line	99,898.53	
Shop	15,907.13	
Instruments	201,089.68	
Furniture and operative appliances	20,940.41	
Hooker telescope	20,320.09	
		358,155.84
Department of Terrestrial Magnetism (inventory to Sept. 30, 1908):		
Office equipment	2,939.70	
Instruments	20,629.35	
Vessel equipment	2,096.12	
		25,665.17
Nutrition Laboratory (inventory to Sept. 30, 1908):		
Office	2,477.31	
Laboratories	5,622.02	
Shop	1,499.71	
Building and site	102,041.23	
		111,640.27
Total		891,739.06

Construction and Equipment of Nutrition Laboratory.

The construction of the Nutrition Laboratory, begun in July, 1907, proceeded so rapidly that Director Benedict and his staff were permitted to occupy it early in January, 1908, a month in advance of the contract requirement. The equipment of this novel establishment has gone on with equal rapidity, so that the laboratory is now substantially ready to begin its program of systematic investigation. A description of this laboratory with appropriate illustrations will be found in the report of the Director in the

current Year Book. It may suffice here, therefore, to remark that it is a fire-proof building admirably adapted to its purposes and provided with an equipment adequate to the new and difficult field of research it is designed to occupy.

Ship for Ocean Magnetic Work.

The signal success of the brigantine *Galilee,* chartered from her owners in San Francisco by the Department of Terrestrial Magnetism in July, 1905, and employed in a magnetic survey of the Pacific Ocean up to May, 1908, led to the approval of a recommendation of the Director of that department to construct a ship specially designed for such work. Authorization of this project was voted by the Executive Committee at its meeting of April 21, 1908, and the preparation of a program of requirements of a non-magnetic ship with auxiliary propulsion for submission to a naval architect was immediately begun. On March 11, 1908, Mr. Henry Gielow, of New York City, was retained to prepare the necessary plans and specifications and superintend the construction of this proposed vessel. The novelty of her requirements has necessitated much study, and the Institution is fortunate in having enlisted the scientific as well as the professional interest of Mr. Gielow in this enterprise. This vessel will be classified as a yacht and, by vote of the Executive Committee at its meeting of May 12, 1908, she will be called the *Carnegie.* A description of her design and equipment will be found in the report of the Department of Terrestrial Magnetism in the current Year Book.

Astronomical Observatory in Southern Hemisphere.

In pursuance of the plans of the Department of Meridian Astrometry, explained in previous reports, for the establishment of a temporary observatory in the southern hemisphere, Professor Lewis Boss, Director of this Department, and his chief assistant, Professor R. H. Tucker, sailed from New York for Buenos Aires on August 20, 1908. The site chosen for their observatory is San Luis, Argentina, situated on the east Andean plateau, at an altitude of about 2,500 feet, and in a locality favorable for clear nights. It is anticipated that the expedition will be ready to begin work early in 1909, since the instrumental equipment will be drawn from the Dudley Observatory of Albany, New York.

Administration Building.

In conformity with the recommendation of the Executive Committee, approved by the Board of Trustees at the meeting of December 10, 1907, a contract for the construction of an administration building on the southeast corner of Sixteenth and P Streets, northwest, Washington, D. C., was let to Messrs. J. E. and A. L. Pennock, of Philadelphia, Pennsylvania, on January 8, 1908. The plans and specifications for this building were prepared by Messrs.

Carrère and Hastings, of New York City, who are also superintending the work of construction. The contract with Messrs. Pennock, whose bid was the lowest of six bids, calls for an expenditure of $210,287. Adding to this 5 per cent for fees of architects for preparation of plans, specifications, and contract, and for superintendence, the cost of the building will be in round numbers $220,500.

A permit for the construction of this building was obtained from the authorities of the District of Columbia on February 27, 1908, and the contract with the builders requires that their work be completed within 400 days from that date. At the time of issue of this report work on the building is so well advanced that it will be fully inclosed before the advent of winter storms.

RÉSUMÉ OF WORK OF YEAR.

General Aspects of Departmental Work.

Ten fully organized departments of the Institution are now actively engaged in the conduct of investigations in as many different fields of research. Each department has its director and staff of collaborators and assistants, and seven of them have laboratories or observatories with appropriate equipments. For convenience of reference the designations of these departments and the names of their directors may be here cited:

1. Botanical Research: D. T. MacDougal, Director.
2. Economics and Sociology: Carroll D. Wright, Director.
3. Experimental Evolution: Charles B. Davenport, Director.
4. Geophysical Research: Arthur L. Day, Director.
5. Historical Research: J. F. Jameson, Director.
6. Marine Biology: Alfred G. Mayer, Director.
7. Meridian Astrometry: Lewis Boss, Director.
8. Research in Nutrition: Francis G. Benedict, Director.
9. Solar Research: George E. Hale, Director.
10. Terrestrial Magnetism: L. A. Bauer, Director.

Of these departments, the first, third, and sixth may be grouped under the head of biological science; the second and fifth under humanistic science; the fourth and tenth under geophysical science; the seventh and ninth under astronomical science; and the eighth under physiological science. There are thus but five of the broader provinces of science represented by the ten departments, and a closer inspection would show that in each province the fields of investigation are strictly limited, as they must be, by the limitations of the Institution's income.

In the light of a more inclusive classification, it will be noted that only two of these departments are devoted to humanistic science, while eight of them are devoted to physical science, assuming that biology is a branch of the latter. This great disparity of representation and the reasons therefor are well worthy of reflective consideration, especially in connection with any plans for enlargement of the work of the Institution.

Theoretical doubts as to the efficiency of the departmental system for the prosecution of research seem destined to vanish in the face of experience now rapidly accumulating. All departments are in fact proving so highly productive that it will not be easy to keep pace with their expanding needs and provide adequate means for the publication of their researches. Strict economies must be enjoined upon them; and they must learn, wherever possible, to increase efficiency by diminishing expenses rather than by enlarging them. In the meantime it should be stated that these departments have been confronted by the adverse economic condition of a continuous rise in prices of commodities and in the cost of living, so that the estimated budgets of two to five years ago now require an increase of 10 to 15 per cent to meet this condition alone.

Along with the development of departmental investigations, many young men of exceptional abilities now attached to the several staffs promise to acquire training and experience which will fit them admirably for work of instruction and research in academic institutions. Since the demand from the latter for able men is increasing, it may be anticipated that in the near future the Institution will be called upon to repay to educational establishments whatever debt has been incurred in drawing from them chiefly in manning our departments.

Referring to the full reports of the heads of departments, published in the present volume, pages 53 to 225, for the more interesting and instructive details, the following summary may serve to indicate some of the salient features of current progress in departmental work.

Department of Botanical Research.

With headquarters at the Desert Botanical Laboratory, at Tucson, Arizona, in the midst of a vast arid region, one of the results to be expected from this department is a descriptive account of the characteristic forms and habitats of desert plants. A preliminary volume devoted to this end was issued as publication No. 6 of the Institution in 1904. Since the latter volume is now nearly exhausted, the issue during the year of a larger volume, publication No. 99, by Director MacDougal, entitled Botanical Features of North American Deserts, is timely both for the needs of the department and for the progress of botanical science. A more technical memoir, entitled Distribution and Movements of Desert Plants, by Professor V. M. Spalding, of the departmental staff, has been recently completed for publication.

Of the numerous promising investigations in progress under this department, it may suffice to cite those of the influx of plants in the receding area of Salton Sea, the general rôle of water evaporation in plant life, the physiology of transpiration in plants, the histology of hybrids, and the effects of altitude, insolation, and other climatic factors. To these should be added the more remarkable experimental researches of Director MacDougal in the

production of new species of plants and in the development, by parasitic growth, of plants less well supplied with water on those better supplied therewith.

Department of Experimental Evolution.

The investigations of this department are rapidly accumulating quantitative data which are destined to furnish important contributions to the definite solution of many difficult problems of plant and animal evolution. It should be noted likewise that the experiments of the department with plants, animals, birds, and insects are not only of great value in themselves, but of growing interest also by reason of their correlations with the investigations of other departments and with those of Research Associates of the Institution. Thus, to mention only one of these correlations, the whole subject of the physical basis of species derives a fresh impetus from the researches of Dr. Osborne on the chemical properties of proteid food-plants and from the researches of Doctors Reichert and Brown on the mineralogical characteristics of blood crystals.

For details of the departmental work of the year, reference must be made to the report of the Director in this volume, pages 86–96. It may suffice here, therefore, to call attention to a single additional matter of administrative import. As explained in previous reports, Dr. G. H. Shull, of the departmental staff, has in preparation a scientific account of the horticultural methods and products of Luther Burbank. In conformity with the plan adopted by the committee (consisting of the heads of departments of biological research and the President) having charge of this work, Dr. Shull was sent abroad in August of this year for the purpose of visiting the principal horticultural establishments of Europe. By aid of this opportunity it is hoped that Dr. Shull may not only become better qualified to place the aspects of Mr. Burbank's work in their proper relations, but that he may also gain knowledge of value in the conduct of his own experiments in plant-breeding carried on at Cold Spring Harbor.

Department of Economics and Sociology.

Noteworthy progress towards completion of its work has been made during the year by the Department of Economics and Sociology. The Director reports that the appropriations already made will probably suffice to bring the researches under way to the stage of publication. The general title adopted for the publications of the department is "Contributions to American Economic History," and several volumes will probably be ready for printing during the ensuing year. As announced in my preceding report, publication was begun in 1907 of indexes, prepared under the auspices of this department, to the economic materials in official documents of the States of the United States. Indexes for the States of Massachusetts,

Rhode Island, and New York have been printed during the past year; an index for the State of California is now in press; and other volumes of this series are in preparation.

The Geophysical Laboratory.

During the past year the equipment of this novel establishment has followed close after the completion of its construction, announced in my preceding report; and it may now be said that the plant and the staff of the Laboratory have attained substantially the standard of opportunity and efficiency desired. Henceforth, therefore, the staff may devote its energies to a systematic study of the origin and transformation of the rocks of the earth's crust by the aid of appliances adequate to cope with the actual conditions of the difficult problems to be solved. The two principal features of these appliances are those which render available as adjuncts in research high pressures and high temperatures, separately or in combination, as may be desired. Hence we may confidently expect from this organization results of great importance with reference to well-known materials, and results of equal importance with reference to the more theoretical questions of the general properties of materials in the earth's mass.

In the preparation of high-pressure apparatus the Laboratory has had the good fortune to secure the services, as Research Associate, of Dr. A. Ludwig, of Dusemond, Germany, who has had exceptional experience in this line of work. By his aid a compressor has been installed which is expected to develop pressures up to 5,000 atmospheres or more.

Simultaneously with the installation of equipment, investigations have been in progress and several technical papers have been published by members of the staff during the year. An outline of these papers is furnished by the Director in his report in this volume, pages 97–106.

Department of Historical Research.

The work of the Department of Historical Research during the past year has proceeded essentially along the lines laid down by the present Director in his first annual report, published in the Year Book for 1906. His department has been occupied, therefore, mainly in the discovery, classification, and cataloging of original documents relating to American history. The field for this work is necessarily a wide one, requiring explorations in many foreign archives as well as in those of the United States. Thus, during the past year, while the government archives in Washington have been one of the main objects of research, investigations have been carried on also in the archives of Mexico, Great Britain, France, and Rome.

Two specially important publications of the Department have been in press during the year, namely: a new and greatly enlarged edition of Van Tyne and Leland's "Guide to the Archives of the Government in Washing-

ton" and "Guide to the Manuscript Materials for the History of the United States to 1783, in the British Museum, in Minor London Archives, and in the Libraries of Oxford and Cambridge," by Professor Charles M. Andrews and Miss Frances G. Davenport. The former of these was issued in February, 1908, and the latter may be expected to appear before the end of the calendar year. For accounts of other noteworthy works in preparation by the Department attention is invited to the Director's report on pages 107–117.

It is a source of gratification to note and to acknowledge here the courtesies rendered to the Department by government officials at home and abroad, by officials of local societies, and by individuals engaged in historical research. The hearty spirit of cooperation thus manifested is an indication of widespread interest in and approval of the work of the Department.

Department of Marine Biology.

The location of the laboratory of this department on one of the Tortugas Islands is proving highly advantageous, in spite of its relative inaccessibility and in spite of its short seasons free from dangerous storms; for these latter drawbacks are more than offset by the great abundance of life available for research, by the immunity of the island from tropical diseases, and by the freedom for continuity of work secured by complete isolation.

Nine associate investigators have availed themselves of the facilities of the laboratory during the past season, and a wide variety of studies has been pursued by them and by the Director. Details of these studies are explained by him in the report of this department on pages 118–138.

It should be observed with respect to the work of this laboratory, as well as with respect to that of the two other biological laboratories of the Institution, that it is primarily occupied with the investigation of physical principles rather than with the collection and classification of marine organisms. Thus, among other researches of the department, those of the Director, on the rôle of concentrated saline solutions in producing the rhythmic pulsations of scyphomedusæ, may be cited as a typical illustration of the kind of work in question and of the broader aspects of biological work in general.

During the winter season of 1907–08, Director Mayer spent several months at the International Zoological Station of Naples in securing supplementary data for his monograph on the Medusæ of the World, the first volume of which is now in press as publication No. 109.

It is of interest to note here that the facilities of the department have been accepted during the year by Dr. W. L. Tower, former Associate of the Institution, who has established vivaria on the grounds of the laboratory for the purpose of extending his remarkable experiments on chrysomelid beetles. Similar facilities also have been extended to Dr. Tower by the Department of Botanical Research, at Tucson, Arizona.

A report on work for the year up to August 15, 1908, was rendered by the Director of the Department of Meridian Astrometry just before he sailed from New York for Argentina, for the purpose of establishing a temporary observatory in that country. Later advices bring an account of the proceedings of his department substantially down to date, and his report in this volume, on pages 139–145, will be found to include the entire fiscal year.

Department of Meridian Astrometry.

With headquarters at the Dudley Observatory, Albany, New York, the department has been occupied with the completion of a preliminary catalog of standard star positions and with preparations for the establishment, in accordance with plans outlined in previous reports, of a temporary observatory in the southern hemisphere.

The preliminary catalog just referred to has been completed and the manuscript is now in hand for printing. It gives the positions of 6,188 stars with a degree of precision hitherto unequaled in this branch of astronomy. The precision of these positions is, indeed, so great as to indicate important corrections to other astronomical data and to disclose remarkable common proper motions in certain groups of widely separated stars.

The observatory in the southern hemisphere will be located at San Luis, Argentina, in latitude about 33.3° south, in longitude about 16.5° west of Greenwich, and at an altitude of about 2,500 feet above sea-level. The meridian instrument of the Dudley Observatory, whose constants have been thoroly investigated, will be transferred to San Luis and used in securing the desired measurements of the positions of stars in both hemispheres. Several members of the staff of the Dudley Observatory will be transferred also to the temporary observatory, so that the observations and computations may be carried on expeditiously and simultaneously.

The department has been especially fortunate in securing the services of Professor R. H. Tucker, of the Lick Observatory, to take charge, as resident astronomer, of this arduous enterprise, which will require three to five years for its completion. The work of observing and computation is expected to be well under way early in the next calendar year.

It is a source of pleasure to acknowledge the cordial assistance uniformly rendered to the department by representatives of the Argentine Republic. Thru their good offices the expedition to their country assumes an international interest peculiarly appropriate to the science of sidereal astronomy.

The attention of the staff of the Nutrition Laboratory has been restricted during the year chiefly to the work of construction and equipment of this unusual establishment. Begun in July, 1907, the building was so far advanced that members of the staff were permitted to take possession in the following January. Construction and installation of equipment proceeded rapidly, considering the quantity and special designs of the apparatus required. Most of the latter

Nutrition Laboratory.

had to be made in the laboratory under the immediate supervision of the Director and his staff.

Attention is invited to a full description of the Laboratory and its appliances given by the Director in his report in this volume, pages 158–162; and it may be remarked that a visit to this establishment will well repay one who is interested in the ways and means there provided for the observation and measurement of the chemical, physical, and physiological factors of human and animal nutrition.

It may suffice here to state that the laboratory is thoroly fire-proof, exceptionally well furnished and equipped, and is now ready to begin the work for which it was specially designed. The items of cost for site and building; for heating, lighting, cooling, ventilating and other apparatus (involving an aggregate of about 4 miles of tubing), and for furniture are given in the table on page 23.

A fact of interest and importance developed in the equipment of this laboratory, and borne out by experience with other laboratories as well, is that it proved highly economical to install the machinery essential to construct special apparatus rather than to have it made by contract. The advantage has proved to be much greater than that measured by the cost of the machinery, which remains available for further use.

The Solar Observatory.

Work of construction and investigation at the Mount Wilson Solar Observatory has been carried forward with a degree of energy and success commensurate with the large investment required by this formidable enterprise. During the year all parts of the 60-inch reflecting, equatorial telescope have been safely transported to the site of the Observatory, the steel dome and building for its reception have been completed, and the instrument is now mounted and substantially ready for use. A spectroscopic laboratory has been erected and equipped at Pasadena and a grinding machine for surfacing the mirror of the 100-inch Hooker telescope has been completed.

The tower telescope described in the Year Book of 1907 has proved to be a most effective instrument in solar research and has led to discoveries with regard to sun-spots of as great importance, probably, to terrestrial and molecular physics as to solar physics. For an account of these discoveries the reader must be referred to the report of Professor Hale in this volume, pages 146–157, and to the accounts and discussions in current journals, since any attempt at explanation in semi-popular language is liable to be premature, if not misleading at the present writing. It may be confidently anticipated, however, that the progress thus inaugurated will lead rapidly to still more important results than those already established.

In the meantime many other lines of investigation are proceeding simultaneously toward an elucidation of the phenomena presented by the sun and similar stars. By aid of the Snow (horizontal) telescope, the tower telescope,

and the 60-inch equatorial reflector now available, photographic, spectrographic, and visual observations may be made; and these may be supplemented by and compared with observations made in the laboratory, where conditions as to temperature and pressure of the gases observed can be controlled and measured.

Many publications from the Observatory have appeared during the year. Most of these, necessarily preliminary publications, have been printed in the Astrophysical Journal.

An important asset in the plant of the Solar Observatory is the road leading to the summit of Mount Wilson. This is about 10 miles long on an average grade of 10 per cent, increasing in some places to more than 20 per cent. It has served admirably for the safe transport of the parts of the 60-inch telescope up the mountain. Some of these single parts weigh as much as 5 tons.

After repeated failures, the glass manufacturers of St. Gobain, France, have succeeded in casting a suitable disk for the 100-inch mirror of the Hooker telescope. This disk is now en route to Pasadena and the work of grinding it should soon be begun.

Department of Terrestrial Magnetism.

The activities of this department have extended during the year to a wide range of localities, and correspondingly satisfactory progress has been made toward a complete magnetic survey of the globe.

The ship *Galilee,* chartered from her owners at San Francisco in July, 1905, completed her third cruise on the Pacific Ocean in May of this year and was then returned to her owners. This cruise was started at San Diego, California, on December 22, 1906, and covered a distance of about 35,000 nautical miles. At the beginning of the present fiscal year the *Galilee* had just set sail from Jaluit for Port Lyttleton, New Zealand. Arriving at this port December 24, she proceeded to Callao Bay, Peru, and thence to San Francisco, where she arrived on May 21, 1908. Altho the ship encountered many delays and dangers in this long voyage, invaluable magnetic data were obtained. Twenty primary and twenty secondary land stations were established and numerous observations of the three magnetic elements (of declination, dip, and intensity) were made at sea. In the three cruises made by the *Galilee* a total of more than 60,000 nautical miles has been traversed, securing thus from this source alone a fairly good magnetic survey of the Pacific Ocean.

Experience with the *Galilee* has demonstrated the practicability of securing on the ocean measures of the earth's magnetic elements of nearly the same precision as those made on land. Mid-ocean measures appear, indeed, to be of greater value than those on land, since the latter are more often subject to local anomalies, and the former are directly applicable to the needs of navigation. The same experience has demonstrated the necessity of having a ship specially designed for ocean magnetic work and provided with

auxiliary propulsion, which will enable work to be done in the vicinity of islands and continents where sailing craft may not go in safety. Hence the action of the Executive Committee in deciding to have constructed a ship for this purpose. Plans for such a ship have been prepared by Mr. Henry Gielow, naval architect and engineer, of New York City, and it is hoped that the contract for her construction may soon be let. A description of this vessel is outlined and illustrated in Dr. Bauer's report in this volume, pages 163–174. With the approval of the Founder of the Institution, she will be called the *Carnegie*. It is of interest to note, however, that this name was predetermined by wide popular interest in this branch of the work of the Institution.

Along with the ocean magnetic survey there have been carried on also extensive observations on widely separated land areas of the continents of North and South America, Asia, Africa, and Europe, for the details of which reference must be made to the Director's full report. In connection with this branch of the department's work it is fitting to acknowledge numerous courtesies from the representatives of foreign governments at home and abroad. The British Ambassador to the United States has been especially helpful in securing credentials to members of the departmental staff who have been at work in or who have traversed British territory.

The conduct of its operations naturally requires a large amount of office work from this department. Much time and attention must be given especially to the testing of all magnetic instruments used on land or sea; while the extensive computations essential to prepare the results of observations for publication are carried on as the field work proceeds, in order to promptly check and correct any defects of instruments or methods. It is expected that the first volume of "Magnetic Results" of the department will be ready for publication in the near future. In the meantime the Director has in press, thru the Government Printing Office, the results of a magnetic survey of the United States along with a set of magnetic maps prepared under the auspices of the U. S. Coast and Geodetic Survey while he was assistant in charge of the magnetic work of that bureau.

Work of Minor Grantees and of Research Associates and Assistants.

As may be seen by reference to the tables on page 20, 31 grants have been made during the year to individuals and to organizations in aid of researches conducted by them. In addition to these, many other researches have been carried forward thru aid of grants made in former years. In all, under this head, about 65 individuals have been engaged in work of investigation during the year. Their range of work includes more than twenty different fields with ramifications into subjects too numerous to be mentioned here. It may suffice to report, therefore, that all of these researches are practically certain to be fruitful and that many of them have already reached the stage of publication of results. Of 19 volumes emanating from this source, 7 have been issued during the year, 5 are in press,

and the manuscript for several others will soon be received. It should be observed also that many preliminary or briefer papers reporting the results of investigations by associates of the Institution have been published during the year in the current journals of the world.

PUBLICATIONS.

The publication of 20 volumes has been authorized by the Executive Committee during the year at an aggregate estimated cost of $48,610. These volumes have emanated from 35 different authors and refer to 7 different fields of investigation.

Publications Authorized and Issued During the Year.

The following list gives the titles and authors of the volumes issued during the year. It includes 27 volumes and 1 atlas with an aggregate of 4,843 octavo pages and of 2,485 quarto pages. The total cost of these volumes is $63,876.44.

List of Publications issued during the year.

Year Book, No. 6, 1907. Octavo, VII + 242 pages, 11 plates.
Index Medicus, Second Series, vol. 5, 1907. Octavo, 1,444 pages.
No. 39. Handbook of Learned Societies and Institutions—North and South America. Octavo, VIII + 592 pages.
No. 43. Observed Positions of Sun-spots. By C. H. F. Peters. (Edited by E. B. Frost.) Quarto, XIII + 189 pages.
No. 54. Research in China: vol. 2, Systematic Geology. By Bailey Willis. Quarto, V + 133 + V pages, 8 plates.
No. 66. High Steam Pressures in Locomotive Service. By W. F. M. Goss. Octavo, 144 pages, 120 text figures, 12 plates.
No. 75. The Fossil Turtles of North America. By O. P. Hay. Quarto, 568 pages, 704 text figures, and 113 plates.
No. 77. The Influence of Inanition on Metabolism. By F. G. Benedict. Octavo, VII + 542 pages, 2 text figures.
No. 78. Synopsis of Linear Associative Algebra: A Report on its Natural Development and the Results reached up to the present time. By James Byrnie Shaw. Quarto, 145 pages.
No. 79. Researches on the Performance of the Screw Propeller. By W. F. Durand. Octavo, 61 pages, 85 text figures.
No. 82. The Physiology of Stomata. By Francis E. Lloyd. Octavo, 142 pages, 40 text figures, 14 plates.
No. 85. Index of Economic Material in the Documents of the States of the United States. Prepared for and under the direction of the Department of Economics and Sociology of the Carnegie Institution of Washington. Separate volume for each State. By Adelaide R. Hasse. Quarto. Massachusetts (1789–1904), 310 pages; Rhode Island (1789–1904), 95 pages; New York (1789–1904), 553 pages.
No. 87. The California Earthquake of April 18, 1906. Report of the State Earthquake Investigation Commission, Andrew C. Lawson, Chairman. Quarto.
Vol. 1 (in two parts). Report of the Commission.
Part I, pages XVIII + 254, plates 1–98, text figures 1–54.
Part II, pages 255–451, plates 99–146, text figures 55–69.
Atlas contains 25 maps relating to volume 1 and 15 sheets of seismograms relating to volume 2.
No. 89. The Old Yellow Book: Source of Browning's "The Ring and the Book." By Charles W. Hodell. Octavo, CCLXII + 345 pages, 4 plates.
No. 91. Guide to the Materials for the History of the United States in Spanish Archives (Simancas, the Archivo Historico Nacional, and Seville). By W. R. Shepherd. Octavo, 107 pages.

No. 92. Guide to the Archives of the Government of the United States at Washington. Revised and enlarged edition of Publication No. 14. By C. H. Van Tyne and W. G. Leland. Octavo, XIII + 327 pages.

No. 93. The Rotation period of the Sun, as determined by the Motion of the Calcium Flocculi. By G. E. Hale and Philip Fox. 54 pages, 2 plates, 5 figures.

No. 94. The Structure and Life-history of the Hay-scented Fern. By Henry S. Conard. Octavo, 56 pages, 25 plates.

No. 95. Inheritance in Canaries. (Paper No. 10, Station for Experimental Evolution.) By C. B. Davenport. Octavo, 26 pages, 3 plates colored to life.

No. 96. Condensation of Water Vapor, as induced by Nuclei and by Ions. Report III. By Carl Barus. Octavo, VI + 139 pages, 48 text figures.

No. 98. The Topography of the Chlorophyll Apparatus in Desert Plants. By W. A. Cannon. Octavo, 42 pages, 15 text figures, 5 plates.
Induction, Development, and Heritability of Fasciations. By Alice A. Knox. Octavo, 20 pages, 1 text figure, 5 plates.

No. 99. Botanical Features of North American Deserts. By D. T. MacDougal. Octavo, IV + 112 pages, 62 plates, 6 text figures.

No. 101. The Variation and Correlation of the Taxonomic Characters of Gryllus. By Frank E. Lutz. Octavo, 63 pages, 6 text figures.

No. 106. Gases in Rocks. By R. T. Chamberlin. Octavo, 80 pages.

Numbers and Costs of Publications in Different Fields of Research.

The Institution has thus far issued in all 120 volumes, which, excluding the Year Books, may be classified under 19 different fields of investigation. It will be instructive, therefore, to note the relative numbers and aggregate costs of publications in the different fields. The data for comparison are supplied in the following table:

Field of research.	Volumes issued.	Aggregate cost.	Field of research.	Volumes issued.	Aggregate cost.
Anthropology	4	$3,500.85	History	8	$3,787.75
Archeology	2	6,101.38	Literature	1	3,354.58
Astronomy	8	18,377.62	Mathematics	5	6,990.89
Bibliography*	7	58,349.83	Nutrition	3	4,141.09
Botany	15	19,733.06	Paleontology	3	15,298.31
Chemistry	9	7,845.60	Physics	7	9,261.30
Economics and Sociology	6	6,774.47	Physiology	1	72.55
Engineering	2	1,532.74	Psychology	1	291.75
Geology	8	29,236.12	Zoology	21	16,770.63
Geophysics	3	3,813.73	Year Books	6	10,603.67

*Includes 6 volumes of Index Medicus (1903–07) at a cost of $54,835.89. Against this amount there should be offset the amount of the subscriptions to and sales of this publication, namely, $17,243.60.

Sales of Publications.

The necessary limitations set a year ago on the free distribution of publications have led to a marked increase in their sale and to a better understanding of the Institution's inability to compete with governmental bureaus in a lavish gratuitous dissemination of books. And altho the broad question of the duties of the Institution to the public in this matter is one which still gives rise to much explanatory and controversial correspondence, it is plain that the policy now adopted will soon meet with general approval. It is apparent also that when the fact becomes generally known that editions of the works

of the Institution are limited to 1,000 copies or less, the public will be willing to buy, at the mere cost of production and transportation to purchasers, the surplus of copies not needed for gratuitous distribution among the greater libraries of the world. This mode of disposition of publications will furnish one of the best standards of their value and will afford at the same time one of the best opportunities for rational cooperation between the public and the Institution.

Storage and Value of Publications.

Attention has been called hitherto to the present serious need, which will be supplied by the Administration Building, of proper storage facilities for books on hand and for those issuing from the press. They are now stored partly in our present office quarters in the Bond Building and partly in the attic of the Geophysical Laboratory. Those in the Bond Building are insured for their full value, while those in the Laboratory are uninsured. There are now on hand, at the end of this fiscal year, in the Bond Building 33,245 volumes, having a sale value of $64,783.50; and in the Geophysical Laboratory 19,959 volumes, having a sale value of $42,920.25. The total sale value of books on hand is therefore $107,703.75.*

* These figures do not include numbers or values for publications Nos. 93, 96, 98, and 106, for which full data are not yet in hand.

REPORT OF THE EXECUTIVE COMMITTEE

REPORT OF THE EXECUTIVE COMMITTEE.*

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the by-laws provides that the Executive Committee shall submit at the annual meeting of the Board of Trustees a report for publication, and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions the Executive Committee herewith respectfully submits its report for the year 1907–1908.

During the fiscal year ending October 31, 1908, the Executive Committee held nine meetings. Printed reports of these meetings have been sent to the members of the Board of Trustees.

Upon the adjournment of the Board of Trustees, December 10, 1907, the members of the Executive Committee met and organized by the re-election of Mr. Wright as Chairman for 1908 and by voting that Mr. Gilbert, Assistant Secretary of the Institution, act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1907–1908, together with various recommendations and suggestions, and also an outline of suggested appropriations for the fiscal year 1908–1909. The Executive Committee hereby approves the report of the President and his recommendations, as the report and recommendations of the Committee, with certain modifications.

There are also submitted a financial statement and a statement of receipts and disbursements for the year, together with a statement of aggregate receipts and disbursements since the organization of the Institution on January 28, 1902.

CARROLL D. WRIGHT, *Chairman.*
JOHN S. BILLINGS.
CLEVELAND H. DODGE.
S. WEIR MITCHELL.
ELIHU ROOT.
CHARLES D. WALCOTT.
ROBERT S. WOODWARD.

WASHINGTON, D. C., *December 7*, 1908.

*For the Year Book this report is printed in abbreviated form.

Financial Statement, October 31, 1908.

		ASSETS.	LIABILITIES.
Endowment			$12,000,000
Reserve Fund:			
Administration Building Fund			283,816.44
Surplus			17,060.36
Premium (sale of bond)			1,500
Bonds (original cost):			
U. S. Steel Corporation bonds, 5 per cent	$12,000,000		
$100,000 A., T. & S. Fe Ry. Co. 4 per cent 100-year gold bonds, Oct. 1, 1995		100,112.50	
$100,000 N. P. Ry. Co. Pr. Ln. Ry. and Ld. Gr. gold bonds, Jan. 1, 1997		101,800	
$50,000 L. S. and Mich. S. Ry. 4 per cent debenture bonds		48,222.22	
$50,000 C. Pacific First Refunding gold 4 per cent bonds		51,937.50	
Real Estate, Equipments, and Publications:			
Administration:			
Building and site (chargeable to Administration Building Fund)	$133,224.89		
Furniture	4,437.63		
		137,662.52	
Publications:			
Stock and outstanding accounts		108,316.85	
Department of Botanical Research (inventory to July 30, 1908):			
Office and library	$3,812.18		
Apparatus	5,508.15		
Buildings	15,089.25		
Grounds, fencing and water supply	5,154.98		
		29,564.56	
Department of Experimental Evolution (inventory to Sept. 30, 1908):			
Office and library	4,928.18		
Laboratory	2,523.44		
Buildings	29,610.95		
Field appliances	4,339.20		
		41,401.77	
Geophysical Laboratory (inventory to Sept. 30, 1908):			
Office and library	6,954.98		
Laboratory	50,959.24		
Shop	10,115.62		
Building and site	99,606.00		
		167,635.84	
Department of Marine Biology (inventory to Sept. 30, 1908):			
Vessels	10,360.66		
Buildings and docks	7,615.24		
Apparatus	900.39		
Furniture and library	1,136.80		
		20,013.09	
Solar Observatory (inventory to Sept. 30, 1908):			
Buildings, grounds, road, and telephone line	99,898.53		
Shop	15,907.13		
Instruments	201,089.68		
Furniture and operative appliances	20,940.41		
Hooker telescope	20,320.09		
		358,155.84	
Carried forward		13,164,822.69	12,302,376.80

Financial Statement, October 31, 1908—Cont'd.

		ASSETS.	LIABILITIES.
Brought forward		$13,164,822.69	$12,302,376.80
Real Estate, Equipments, and Publications—Cont'd.			
Department of Terrestrial Magnetism (inventory to Sept. 30, 1908):			
Office equipment	2,939.70		
Instruments	20,629.35		
Vessel equipment	2,096.12		
		25,665.17	
Nutrition Laboratory (inventory to Sept. 30, 1908):			
Office	2,477.31		
Laboratories	5,622.02		
Shop	1,499.71		
Building and site	102,041.23		
		111,640.27	
Property investment (aggregate cost)		.....	866,831.02
Grants:			
Large		.....	163,551.71
Minor		.....	18,405.47
Research associates and assistants		.....	8,608.74
Publication		.....	62,449.25
Administration		.....	12,615.70
Cash		155,833.37	
Unappropriated fund		.....	23,122.81
		13,457,961.50	13,457,961.50

Statement of Receipts and Disbursements, November 1, 1907, to October 31, 1908, Inclusive.

RECEIPTS.		
INTEREST:		
U. S. Steel Corp. bonds	$550,000	
A., T. & S. Fe Ry. "	4,000	
N. Pac. Ry. Co. "	4,000	
N. P. Gt. N. "	1,000	
Central Pacific "	2,000	
L. S. and Mich. S. "	2,000	
Deposits in banks	4,761.55	
		$567,761.55
SALES OF PUBLICATIONS:		
Index Medicus	3,406.19	
Year Book	99.65	
Miscellaneous	4,371.67	
		7,877.51
REFUND ON GRANTS:		
Grant No. 478	5.68	
Grant No. 472	20	
		25.68
MISCELLANEOUS:		
Sale of metal	3.30	
Sale of paper	30.84	
Sale of N. P. G. N. bond	48,000	
		48,034.14
		623,698.88
Balance from last report to Trustees, Oct. 31, 1907		208,297.50
		831,996.38

DISBURSEMENTS.		
INVESTMENT:		
Building (administration)		$68,209.80
GRANTS:		
Large	$448,404.65	
Minor	46,350	
Research associates	14,932.11	
		509,686.76
PUBLICATION		49,991.55
ADMINISTRATION:		
Trustees	1,944.50	
Executive Committee	2,071.59	
Salaries	26,878.34	
Temporary employees	5,311.35	
Insurance and surety	637.45	
Rent and telephone	3,255.55	
Furniture	200.25	
Office supplies	1,839.20	
Postage, express, etc.	3,371.92	
Printing	* 2,744.41	
		48,254.65
MISCELLANEOUS:		
Publications		20.25
		676,163.01
CASH IN BANKS:		
U. S. Trust Co., N. Y.	151,503.37	
National City Bank, N. Y.	3,429.94	
Am. S. & T. Co., D. C.	900.06	
		155,833.37
		831,996.38

* Including Year Book for 1907.

Statement of Aggregate Receipts and Disbursements, January 28, 1902, to October 31, 1908.

RECEIPTS.		
INTEREST:		
U. S. Steel Corp. bonds	$3,300,000	
A., T. & S. Fe Ry. "	21,000	
N. Pac. Ry. Co. "	20,500	
N. P. Gt. N. "	9,500	
Central Pacific "	8,000	
L. S. and Mich. S. "	10,000	
Deposits in banks	63,579.72	
		$3,432,579.72
SALES OF PUBLICATIONS:		
Index Medicus	17,247.20	
Year Book	322.20	
Miscellaneous	8,445.07	
		26,014.47
REFUND ON GRANTS		5,659.76
MISCELLANEOUS:		
Organization	1,825.52	
Sale of furniture	69	
Gas deposit	5.36	
Postage, express, and travel	34.75	
A. G. Mayer	669.70	
Printing and paper	177.12	
Sale of N. Pac. Gt. Nor. bond	48,000	
Sale of metal	3.30	
Sale of paper	30.84	
		50,815.59
		3,515,069.54

DISBURSEMENTS.		
INVESTMENT:		
Bonds	$348,572.22	
Administration Bldg., site and construction	133,224.89	
		$481,797.11
GRANTS:		
Large	1,650,714.85	
Minor	626,085.86	
Research associates	90,341.26	
Special (of 1904–1905)	37,498.84	
		2,404,640.81
PUBLICATION		190,579.48
ADMINISTRATION:		
Trustees	8,652.29	
Executive Committee	10,020.54	
Advisory Committees	5,859.81	
Honorariums	11,460	
Salaries	142,525.25	
Temporary employees	27,901.57	
Insurance and surety	1,908.57	
Rent and telephone	22,000.34	
Furniture	6,104.88	
Office supplies	9,763.08	
Postage and express	13,949.13	
Printing	* 14,348.26	
Organization	1,825.52	
Plans and option	5,166.46	
Seal	555.60	
Miscellaneous	70.23	
		282,111.53
PUBLICATION REFUND		20.25
INDEX MEDICUS REFUND		86.99
		3,359,236.17
CASH IN BANKS:		
U. S. Trust Co., N. Y.	151,503.37	
National City Bank, N. Y.	3,429.94	
Am. S. & T. Co., D. C.	900.06	
		155,833.37
		3,515,069.54

* Including Year Books.

REPORT OF AUDITOR.*

WASHINGTON, D. C., *November 23, 1908.*

The Executive Committee of the Carnegie Institution of Washington.

GENTLEMEN: The books of account of the Carnegie Institution of Washington have been audited by us from November 1, 1907, to October 31, 1908, by authority of the Chairman of the Board of Trustees.

The income from the Endowment Fund and from investments has been duly accounted for, and the expenditures have been regularly authorized and are supported by proper vouchers.

On Thursday, November 12, 1908, the undersigned, Mr. Luebkert, in company with the Chairman of the Board of Trustees, attended at the vaults of the Hudson Trust Company, Hoboken, N. J., and examined the bonds of the Endowment Fund, finding same on hand and in proper order. On Friday, November 20, 1908, Mr. Luebkert, in company with the Bursar, Mr. John L. Wirt, and Mr. W. M. Gilbert, visited the vaults of the American Security and Trust Company, Washington, D. C., and examined and found correct and in good order the securities comprising the Reserve Fund and Investment accounts.

Respectfully submitted.

THE AMERICAN AUDIT COMPANY,
By OTTO LUEBKERT, *Resident Manager.*

Approved:
F. W. LAFRENTZ, *President.*

[Seal of The American Audit Company, New York.]

Attest:
A. F. LAFRENTZ, *For Secretary.*

*For the Year Book the Auditor has abbreviated his report.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK ACCOMPLISHED BY GRANTEES AND ASSOCIATES.

Under this heading it is sought to include the titles of all publications bearing upon work done under grants from the Carnegie Institution of Washington. In the list for the past year, as shown below, there may be some omissions, although it has been the endeavor to make it as complete as possible, and in some cases titles may be included which have only an indirect connection with such work. The titles of papers by investigators of the Department of Economics and Sociology are given in the report of the director of that department, pp. 74–85. A list of the works published by the Institution during the year will be found in the President's report, on pp. 34–35.

Acrée, S. F. On the reactions of carbonyl compounds with hydroxylamine and hydroxylamine hydrochloride. (Amer. Chem. Jour., v. xxxix, No. 2. Feb., 1908.)

———. On the theory of indicators and the reactions of phthaleins and their salts. (Amer. Chem. Jour., v. xxxix, No. 4. Apr., 1908.)

———. Ueber die reactionen tautomerer saeuren und salze mit diazomethan und alkylhaloiden. (Berichte der deutschen chemischen Gesellschaft, v. xli, pp. 3199–3236.)

———. On the velocity constants and mechanism of the reactions of alkyl halides with urazoles and urazole salts. (Amer. Chem. Jour., v. xxxix, pp. 226–277.)

———. Studies in Catalysis: On the hydrolysis of amides by acids. (Amer. Chem. Jour., v. xxxviii, pp. 489–507.)

———, and Hinkins, J. E. On abnormally acid saliva. (Dental Review. Apr., 1908.)

———, and Slagle, E. A. On the theory of indicators and the reactions of phthaleins and their salts. (Amer. Chem. Jour., v. xxxix, No. 6. June, 1908.)

Adams, Walter S. Spectroscopic observations of the rotation of the sun. (Astrophys. Jour., v. xxvi. Nov., 1907.)

———. Preliminary catalogue of lines affected in sun-spots. (Astrophys. Jour. v. xxvii. Jan., 1908.)

———. Preliminary note on the rotation of the sun as determined from the displacements of the hydrogen lines. (Astrophys. Jour., v. xxvii. Apr., 1908.)

Allen, E. T., and J. K. Clement. The rôle of water in tremolite and certain other minerals. (Amer. Jour. Sci., v. xxvi, p. 101. 1908.)

———, and White, Walter P., with optical study by F. E. Wright and E. S. Larsen. Diopside and its relation to calcium and magnesium metasilicates. (Amer. Jour. Sci. Jan., 1909.)

American School of Classical Studies in Rome. Supplementary Paper, v. ii. 1908.

Anderson, J. A. See Jones, H. C.

Aston, J. See Hirsch, A.

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REPORTS OF INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1908, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

The facilities of the Department have been directed toward the study of basic problems in physiology, morphology, phylogeny, and geography of plants, with what success may be denoted by the appended detailed descriptions. The Desert Laboratory remains the chief locus for experimentation and investigations within the scope of the Department, but the development of the work upon questions that have arisen and press for solution has led to the establishment of almost continuous field-work about and on the Salton Sea in Southern California and in the Pattie Basin in Baja California, over 300 miles distant from Tucson, and to the development of the mountain plantations in the Santa Catalina Mountains, the farthest of which lies 32 miles away and is to be reached only by two days' riding on horseback. It seems desirable at the present time to make some similar extensions to localities some distance to the southward in Mexican deserts.

It is very gratifying to record that a large amount of valuable work has been accomplished by the cooperation of the members of the staff with one another and with persons from many other institutions. This is especially exemplified by the work of Professor Spalding, who has secured the attention of a half dozen other workers to certain features of the region in which he has carried on a very exact phytogeographic survey. Drs. Livingston and Shreve, during 1907 and 1908, have been so fortunate as to receive the active, painstaking cooperation of over 40 observers at various places in North America in testing the evaporating power of the air by means of the newly devised atmometer. It would have been impossible to obtain the data at hand except by such aid. Other arrangements of the same kind are described in a section of this report (see p. 68). So far as the operations of this Department are concerned, the facts point unerringly to the conclusion that the only efficient method of "cooperation" is that by which combination of facilities, coordination of effort, and development of opportunities is arranged between members of the staffs of two institutions with the approval of the administration, rather than by formal institutional participation. The most important feature of such arrangements is the personal element and individual contact of the workers involved. Perfect adjustment with respect to these features will make possible results of far greater value than might come from concurrent resolutions by boards of trustees.

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*Address: Desert Laboratory, Tucson, Arizona. Grant No. 473. $29,240 for investigations and maintenance. (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.)

MOVEMENTS OF VEGETATION AROUND THE SALTON SEA.

The phenomena presented by the reoccupation of the emersed areas around the Salton Sea by plants have been of a pronounced character and the reactions observed have been capable of easy interpretation. From the maximum, which was reached on February 10, 1907, to February 10, 1908, the level of the water fell 40 to 42 inches. This recession laid bare beaches a few feet in width on the steeper slopes and over 400 yards in others, and was accompanied by an increase of the salt content from 333 parts in 100,000 in February, 1907, to 364 parts in June, 1907, and 460 parts in June, 1908. The analyses also show that the amount of organic matter in the water is less than at the time of maximum depth of the water. Some algæ clinging to the rocks along the shore include all of the aquatic vegetation at the present time, while the fauna appears to be limited.

The wave action on the steeper gravelly shores is operating to produce terraces, dunes, and tide pools, with an accompanying sorting action of the material moved. The results of similar action on old beaches higher up are still denoted by differentiated bands of vegetation after many hundreds or perhaps thousands of years.

Results of somewhat wider importance, however, are being obtained on gentler slopes, such as those presented by observational area No. 1, in which the soil before immersion was highly impregnated with alkaline salts. The water of the lake being less salty, dissolved out much of the alkali, so that as it receded the plants from the shore found this area too little salty and are occupying portions of it with difficulty. Capillary action, however, is bringing additional quantities of alkali to the surface, so that these plants will gradually spread over and reoccupy the zone. On the other hand, myriads of seeds of species inhabiting areas in which the soil contains but little salt are stranded by the receding water and germinate in the moister soil. As it gradually becomes drier, and the alkali in the surface layers increases, the individuals arising from the water-sown seeds come into an increasing degree of stress with these factors. Thus many thousands of arrow-weed (*Pluchea sericea*) and cat-tail (*Typha angustifolia*), as well as other species in lesser numbers, are annually sown in the most recently emersed zone, and as this becomes drier and saltier a selective action is exerted which reduces the number alive in such an area until a year later it is but a small fraction of the original. Each season adds another band to the series, and it remains to be seen whether or not this selective action will result in the survival of any individuals much beyond that of the mass, and the final fate of their progeny.

At the present stage of the investigation the efficiency of water as an agency in the dissemination of plants is emphatically demonstrated. Wind as a direct and independent factor has been operative to but little extent in the revegeta-

Vivaria and shelters for acclimatization cultures of beetles and plants at Desert Laboratory.
Terrace with marginal dune, tide-pool, and caving bank, near Tavertine Point, Salton Sea, February, 1908.

PLATE 1

tion of the beaches; but it acts as a great cooperating force by carrying clouds of winged seeds to the lake, into which they fall and are distributed by wave and current action. The small drainage channels that cut down the long, gentle slopes of the basin have been very important features in bringing the plants of the upper slopes to the emersed zones around the lake.

The recent emergence of two small islands which were submerged for nearly a year will give an opportunity for a more distinctive test of the various factors in dissemination, including the activities of birds and other animals. No such effects are yet to be seen. It is proposed to follow the history of these islands somewhat closely, as no such opportunity for the observation of the course of vegetation on an isolated bare area, since the destruction of the plants on the island Krakatoa in the Indian Ocean in 1883, has been presented. In the latter instance it was possible for the observers to visit the island only at intervals of several years and no opportunity was had to make an analysis of the processes involved.

The observations on the Salton Sea have so far been carried on by means of a small sailboat and a sectional steel rowboat capable of being easily carried overland to convenient points around the shore. It will soon be necessary to add a houseboat or floating laboratory, by means of which workers may carry on observations more efficiently three or four months in the year.

ACCLIMATIZATION: THE INDUCTIVE INFLUENCE OF PHYSICAL FACTORS ON VEGETATION.

The plantations as described in the report for 1907 have been maintained, and in addition a duplicate plantation has been established in the dry mid-mountain belt in Soldier Canyon, at the eastern end of the Santa Catalina Mountains. The measurement of the various climatic factors at these stations is being carried out, those nearest the Desert Laboratory having received the most attention so far. The range of conditions embraced in these stations runs from a season of about a hundred days (the time between the occurrence of the last freezing temperature, early in June, to a recurrence in September) at the alpine plantation, down to the Desert Laboratory, where the air is not below the freezing point more than 10 hours in a year. The intensity of the insolation must vary in a large degree among the different plantations, although not yet measured or estimated. The precipitation at the Desert Laboratory has an average of about 12 inches yearly, while that of the alpine station can not be less than 30 inches. The evaporating power of the air as determined by atmometers during the vegetative season of the alpine plantations, is about two and a half times greater at the Desert Laboratory, while for the year the total at this station must be ten times that of the high plantation. The total heat exposure at the Desert Laboratory for a year has been esti-

mated to be 325,385 hour-degree Fahrenheit units, while that of the alpine plantation can not be more than one-fifth this amount. Exact series of measurements of all of these factors during two or three seasons will be necessary at all of the plantations in the furtherance of this work.

About 20 species from near sea-level on the Atlantic coast are now established in stations at various levels, some having been brought in from southern Mexico, while a number of local forms are exchanged among the various plantations. It is worthy of record that among the introduced and exchanged species are several which have proved capable of enduring the range of climatic conditions furnished by differences of a vertical mile in elevation.

During the present year, three solanums from southern Mexico have been added to the experimental material, these plants being food-plants for the beetles (Leptinotarsæ) from the same region, being grown at the Desert Laboratory by Prof. W. L. Tower, in his study of the influence of climate on heredity and evolution. (See p. 69 for a fuller account.) The response of the plants and of the beetles taken together may be expected to furnish some important results, and the facts already at hand seem to warrant the extension of this part of the experiment in every possible way.

The greatest value of acclimatization cultures is not to be realized by obtaining simple records of apparent changes in organisms, such as have chiefly been derived from the few systematic experiments which have been previously carried out elsewhere, but rather in exact estimations of the responses of plants or animals in alterations of form, structure, and functional performance with relation to measured environmental factors. Five problems or groups of questions have already been taken up in this manner.

(1) The climatic experiments of Professor Tower already mentioned.

(2) A study of the influence of climates on heredity of lineal series of plants introduced and exchanged. Seeds of the second generation of some species are now on hand and may be tested in the new locality or original habitat.

(3) An exact determination of the part climatic factors may play in transmission and dominance of characters in hybridization. Three pairs of species are now in cultivation and reciprocal crosses are being made at various elevations in order to ascertain the possible influence of climate, both on the composition of the offspring and on the factors governing survival.

(4) Comparative cultures are being made of forms which pass as closely related species growing at different altitudes under different combinations of climatic factors.

(5) The structure and performance of foliar organs under divergent climatic conditions. The different structures exhibited by leaves of individuals of a species at 8,000 feet and others at 2,600 feet are being made out, and an attempt is being made to interpret these with regard to their physio-

logical requirements. The studies of the aquatic *Roripa americana*, originally from the muddy bottom of Lake Champlain, begun in 1902, and since grown in the system of plantations connected with the Desert Laboratory, may be expected to be brought to a definite advanced stage within the next year.

DISTRIBUTION AND MOVEMENTS OF DESERT PLANTS.

The investigations upon the distribution of desert plants carried on by Prof. V. M. Spalding, assisted by Mrs. E. S. Spalding during the past four years, have reached a stage in which some decisive generalizations may be made, and a manuscript setting forth the results in question has been transmitted for publication. Professor Spalding and his cooperators have made a close analysis of the geological history, nature of the soil-formations, relation of physical factors to local distribution, seasonal march, and determining factors in grouping or association of plants, the whole probably constituting the most thorough, comprehensive, and exact study of any area yet made, with respect to these features.

Among the principal conclusions warranted by this work the following may be cited:

(1) Within the limits of the Desert Laboratory domain and that part of the Santa Cruz Valley immediately adjacent, chosen as a representative area for the study of desert plants in southern Arizona, twelve plant associations have been recognized and defined. These fall naturally into four groups corresponding with the main topographical features of the area under observation. The local distribution of certain species of these associations has been carefully mapped with special reference to topographical and soil relations, by this means confirming conclusions based on previous observations.

(2) Observations within this limited area, supplemented by comparative studies in the Gila Valley and elsewhere, have led to the conclusion that soil properties and aspect are of paramount importance in determining the local distribution of desert plants. Evidence has been gained that soil-water exercises a controlling influence, but that, with certain species at least, aeration and percentage of alkali salts are also efficient factors.

(3) The importance of aspect in determining distribution in closely adjacent areas has been established, the selective element being the range in temperature.

(4) Inherited habits and structures, together with the capacity for adjustment or accommodation, are the most important features of the plant involved.

(5) The inter-relations of desert plants are not of a simple nature, but it seems evident that the competitive struggle among them is as intense as in other areas.

(6) No special agencies or methods of dissemination of seeds or propagative bodies were discovered.

(7) The species considered (less than 500 in number) are of diverse geographical origin, including forms whose centers of dispersal range from subtropical America to regions near the Arctic Circle. The major movements by which these forms have come to their present occurrence have been gradual and continuous since the Tertiary Period. Some portions of the area studied are of more recent origin, but these have received a floral population from the immediate neighborhood. The total amplitude of climatic change since the Tertiary Period may be taken to be comparatively small, no greater perhaps than the range now presented by the location of the Desert Laboratory (2,663 feet), and the summit of the Santa Catalina Mountains (9,225 feet). The present floras of these two places are probably more diverse in character than the Tertiary and present floras of the Laboratory domain. During all of the period in question the flora has been composed of two distinct elements—the mesophytic species of the moister elevated regions and the xerophytic forms of the arid slopes and plains.

CORRELATED PROBLEMS.

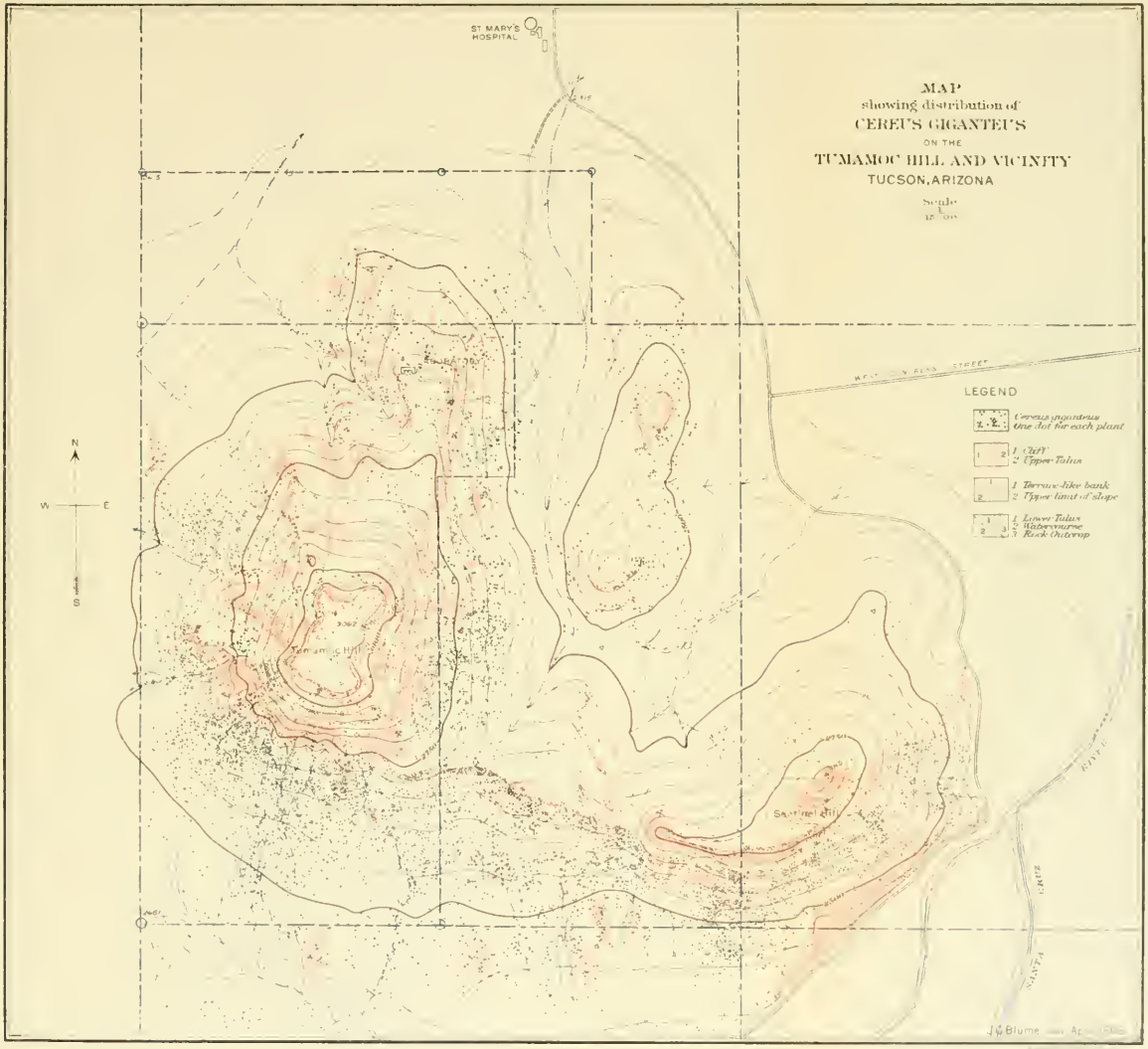
Evaporation and Plant Distribution.—The investigation of the evaporating power of the air as a total expression of the factors that determine the general distribution of plants has been carried forward by Dr. Livingston and Dr. Shreve, with peculiarly satisfactory results.

Atmometers have been kept in operation during the season of 1908 at 50 stations (see p. 68), and the data at hand establish with fair conclusiveness that the amount of water taken up by the air at any given locality during the vegetative season is an infallible index of the character of the vegetation of the encompassing region. As an illustration the following table may be cited:

Relative Evaporating Power of the Air at 16 Stations in the United States, June 3 to September 30, 1907.

Station.	June.	July.	August.	September.	Average.
Mecca, California	349	368	303	278	323
Laramie, Wyoming	322	311	286	274	298
Tucson, Arizona	338	228	212	282	262
Salt Lake City, Utah	92	285	272	227	222
Austin, Texas	225	166	168	215	192
Raleigh, North Carolina	120	188	269	151	158
Eugene, Oregon	90	196	208	98	152
Gainesville, Florida	.....	133	169	122	*143
St. Louis, Missouri	112	157	140	137	137
Burlington, Vermont	120	130	132	63	112
Lincoln, Nebraska	96	90	113	144	111
Chicago, Illinois	93	95	109	95	98
Orono, Maine	81	91	96	67	84
Newark, Delaware	98	97	77	63	83
Grand Rapids, Michigan	70	82	105	54	79
New York City	.....	48	63	35	*50

*Average for 13 weeks instead of 17.


ST. MARY'S HOSPITAL
MAP
showing distribution of
CEREUS GIGANTEUS
ON THE
TUMAMOC HILL AND VICINITY
TUCSON, ARIZONA
Scale
1
15 000
WEST ELEVEN STREET
LEGEND
Cereus giganteus
One dot for each plant
1 Cliff
2 Upper Talus
1 Terrace-like bank
2 Upper limit of slope
1 Lower Talus
2 Rubbervarse
3 Rock Outcrop
N
W
E
S
Tumamoc Hill
Sentinel Hill
SANTA CRUZ
J.W. Blume

The rates at Tucson, Mecca, Salt Lake City, Austin, and Laramie are clearly indicative of desert conditions and denote xerophytic vegetation. The relative amount of water loss at Chicago, Grand Rapids, Burlington, and Orono is found to be characteristic of areas in North America inhabited by conifers. The greater losses at St. Louis, New York, Newark, and Raleigh point indubitably to a forest-covering of deciduous trees. The surveys of 1908 will doubtless result in the acquisition of data in which a more definitive analysis of the matter may be made.

From a local series of instruments, extending from the Desert Laboratory domain at 2,663 feet and 3,095 feet down across the mesa-like slopes up to the plantations in the Santa Catalina Mountains to the northward, it has also become apparent that the determination of the evaporating power of the air furnishes a very valuable criterion for the comparison of different plant habitats and for the analysis of the plant population of any habitat. Thus the following average weekly rate was found:

1907.		1908.		1908.	
Altitude (feet).	Weekly rate.	Altitude (feet).	Weekly rate.	Altitude (feet).	Weekly rate.
2,412	289	2,300	265	5,200	121
6,000	238	2,400	463	6,200	113
7,500	147	2,685	354	8,000	85
8,000	133	3,000	130	8,400	101
		4,000	137		

The examination of the topographic features of the habitats tested shows that the irregularity of the decrease of evaporation from lesser to greater elevations is due to the action of hot dry winds in the direct lee of which some of the stations lie. In all such cases the vegetation of the lower slopes is carried above its average limit of distribution.

Physiological Regulation of Transpiration.—No subject is of more importance in the physiology of plants of dry regions than that of water loss, and Dr. Livingston has continued his studies upon relative transpiration with mesophytic forms under humid conditions to obtain data for comparison with results at the Desert Laboratory. One plant which has been thoroughly tested shows a close connection between the diameter of the stomatal openings at any time and the relative transpiration. Also, by the use of the cobalt method of estimating transpiration, in connection with the atmometer previously designed by Dr. Livingston, it is possible to determine with fair exactness the total water-loss of any plant without disturbance to more than a few leaves or to a comparatively small proportion of its transpiring surfaces.

Desert Soils and Soil-moisture.—Dr. Burton E. Livingston has continued his observations on the principal soil formations of the regions about Tucson. Especial attention has been given to the adobe clays of Tumamoc Hill, to the shallow formation underlaid with caliche and bearing the creosote-bush, and to the broad beds of sandy washes, as well as to those of the river flood-plains. The march of the soil-moisture in these places has been followed and the more important features in the variations estimated. The minimum amount of water for plant activity is about 30 per cent. In the course of this work Dr. Livingston has been able to devise a simple apparatus by which a porous cup filled with water and buried in the soil may give a continuous record of the amount of soil moisture present.

The Plant Life of Maryland.—Dr. Forrest Shreve has been engaged since his accession to the staff in the completion of his treatise embodying the result of four seasons' field work carried on under the auspices of the State Weather Service of Maryland. The distribution and associations of the vegetation have been investigated in relation to the climate, geological features, soils, and topography, and a list of the species compiled. The bringing of these freshly accumulated facts into comparison with similar data from the desert has resulted in some broader generalizations.

Histological Studies on Hybrids.—The examination into the anatomy of hybrids and their pure parents, which was carried on during the summers of 1907 and 1908 by Dr. W. A. Cannon and mentioned in the Year Book of 1907, has been concluded. The investigation included the following forms: *Juglans californica* × *Juglans nigra, Juglans californica* × *Juglans regia, Oenothera lamarckiana* × *Oenothera cruciata, Papaver somniferum* × *Papaver orientale, Papaver somniferum* × *Papaver pilosum,* and *Solanum villosum* × *Solanum guinense.* The observations were confined to the trichomes, whose embryonic and mature conditions were studied and compared. Some of the conclusions may be presented in brief here; an account of the research will be given later in another place.

In *Oenothera* three types of trichomes were seen in the pure species and in the second and third generations of the cross. Numerous measurements on the length of the trichomes show that those of the hybrid are intermediate in size, but not strictly so. The different types of trichomes behave in an independent manner as regards their distribution, a circumstance that points to the necessity, in studies on heredity, of analyzing their distribution in place of grouping all types, as is the present custom. The *Papaver* hybrids were either quite sterile, or only partly fertile; the first generation alone was brought under observation. Although the first generation of either hybrid was in general appearance not intermediate, in certain structural characters this was the

condition of the trichomes of both hybrids. In *Solanum* four types of trichomes are to be found, of which one is common to both pure lines and is to be seen in the cross also; two are peculiar to *Solanum villosum* and do not occur in the hybrid in either the first, the second, or the third generation, and the fourth, which is found in *Solanum guinense* and not in the other pure line, appears undiminished in size in the cross. The trichomes of *Juglans*, of which there are five types, are with one exception multicellular and each type has its peculiar life-history, which is adhered to with great, perhaps with perfect, consistency. This fact, should it be found to be of general application, would suggest the use of multicellular trichomes whenever possible or desirable as an aid in determining the relationships of closely related species and as supplemental to embryogeny proper. A comparative study of the different types of trichomes of *Juglans* shows certain developmental sequences which are experienced in common by them all, so that the mutual relationships of the different forms can be investigated and possibly their structural origin can be traced. In all pure species and hybrids the trichomes were found to vary considerably in size, but this variation was seen to be closely associated with the position occupied by the trichome on the plant member. From the high degree of consistency which the variation exhibited as related to position, as well as because of the wide range of the phenomenon, it was concluded that the minor fluctuations were in some manner to be associated with an unequal food supply, or nutritive conditions, rather than with direct transmission of such qualities from the pure lines, or with the incident of the cross. Throughout the course of the investigation, watch has been kept for structural evidences of unit-characters, or of anatomical attributes of unit-characters. Although no conclusive results were derived, certain suggestions were obtained which ought to be of service in any investigation on this general topic. For instance, in *Oenothera* it was evident that the trichomal system could not be taken in its entirety and be properly considered a *single* character, since each of the three types had a different and apparently an independent distribution. Again, in *Juglans* it is possible that the origin of a unit-character can be traced in the origin and differentiation of the different related types of trichomes. Such observations point to the need, where the inheritance of qualities is being carefully studied, of closer anatomical investigations than are usually made.

Root-habits.—In a research on root-habits, which is being made by Dr. Cannon, it is proposed to include the leading types of plants which occur naturally in the vicinity of Tucson, and so far as possible to extend the study of plants of other arid regions for purposes of comparison, as well as for the purpose of extending our knowledge of the roots of plants. The studies will include the most important features of the external and the internal morphol-

ogy, the relations of the character of the root-system to the distribution of the plants and to their general habits, and so far as possible experiments designed to show the factors by the action of which the leading characters of the roots have risen.

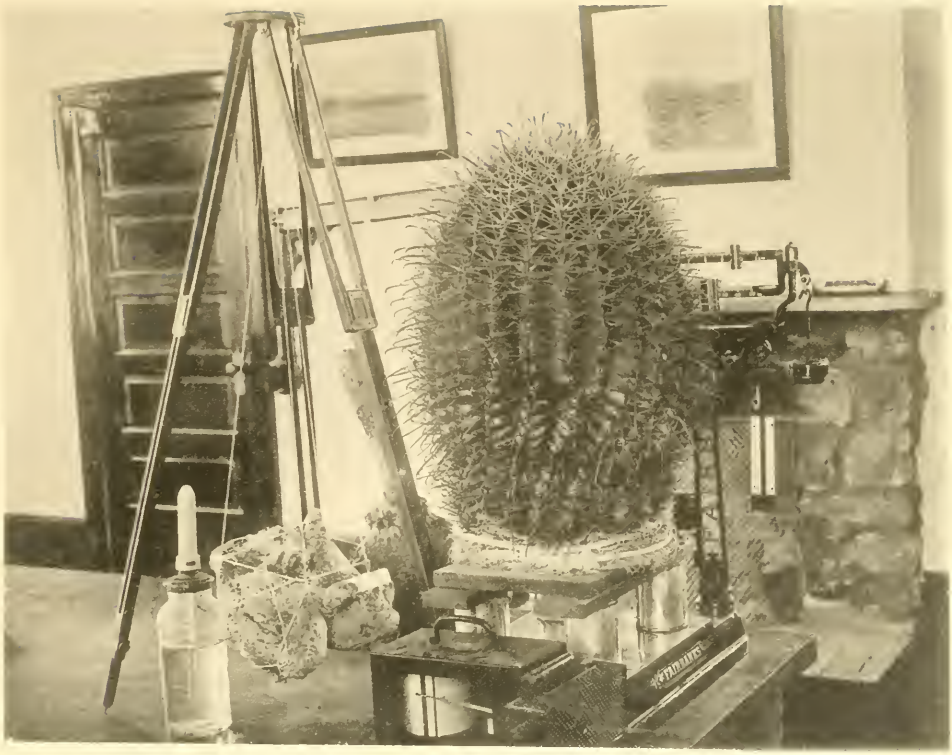
Among the recent noteworthy observations on the habits of the roots of the cacti may be given the discovery of vegetative reproduction in *Opuntia arbuscula* (in the region about Tucson) through its fleshy roots, and the fact that the form of this species growing in the vicinity of Sacaton, Arizona, is not provided with fleshy roots.

The Physiology of Genetics.—The experiments of Dr. D. T. MacDougal, by which the reproductive elements of the higher plants were subjected to the action of chemical compounds of various kinds, inducing breaks in heredity, have been continued and some progress has been made both in the effectiveness of the methods used and in the analysis of the results.

The general method of operation consists in injecting solutions of calcium, potassium, iodine, or zinc into ovaries at some time within 24 hours of the advent of the pollen-tube and the accomplishment of fertilization. The reagents in plants such as *Cereus* were found to be absorbed by the walls of the cavity from which the stalked egg-apparatus arises and through which the pollen-tube must pass in reaching the eggs. By the use of staining solutions it was seen that the reagent in discernible quantity penetrated as far as the outer part of the inner integument of the embryo-sac nearest the antipodal cells, from which it was separated by several protoplasts. More effective concentrations are brought in actual contact with the thin walls of the advancing pollen-tube so that the weight of probability at the present stage of information suggests that the method actually influences the pollen-cell rather than the embryo-sac, although the reverse may be true in some species not yet examined as to this point. Breaks in heredity, discontinuous inheritance, or mutations have been taken on theoretical grounds to consist in changes ensuing previous to the reduction divisions in the reproductive elements, but the effects secured by this method result from action after the second or third division following reduction division and after a comparatively long period of time. The results in question may be more similar to those shown in sports or bud-mutations than those of seed-mutations.

The striking form originally secured from *Oenothera biennis* by this method has been cultivated through several generations, transmits all of its characters fully, and does not readily hybridize with the parent.

Great difficulty was experienced in securing proper germination of the forms treated in the early season of 1907, but of the seven species experimented with *Cereus giganteus* yielded a progeny some of the individuals of which depart far from the usual type. The most striking results, however, are obtained



A

B

A. Echinocactus wislizeni and Ibervillea sonoræ suspended in air to test endurance and rate of water-loss.

B. Parasitism of Cissus digitata on Opuntia sp.

COCKAYNE, BOSTON

with *Pentstemon wrightii* or beard-tongue, a member of the Scrophulariaceæ which is native immediately around the Desert Laboratory. Ovaries were injected with three reagents as noted above and the seeds germinated in the autumn of 1907. Of the 60 individuals that came into bloom, 30 per cent departed so far from the normal as to make the differences apparent even to the novice. The atypic derivatives comprised 8 separate forms, one of which was represented by 5 individuals and another by 4. Some of the departures were very obvious retrogressive changes, consisting in the loss of structural characters; others showed the acquisition of characters not hitherto observed by the investigator within the limits of the genus. This was particularly true of a form in which the lobes of the corolla were conspicuously recurved.

It is believed that a further study of this method may result in our ability to modify the entire progeny of a plant, and furthermore to give these modifications definite trend or direction, by which man might control the evolution of other organisms and produce relations among living things not now existent.

Water Storage and Xeno-parasitism.—The investigation of the mechanism of water-storage by succulents native to arid regions has engaged considerable attention by Dr. MacDougal during the year with the attainment of some definite progress. Some previous record has been made of the fact that many storage plants carry a supply of water which would enable them to exist for a quarter of a century without receiving further supplies. A number of tests of other species, including several cacti, are being carried on to determine the efficiency with which the specialization has been developed in various forms. Of the results at hand those obtained from a great barrel-cactus (*Echinocactus wislizeni*) may be mentioned. A well-grown individual of medium size, weighing 94 pounds in March, has been mounted on a base suitable for weighing, by which it is seen to lose weight at the rate of about 1 pound avoirdupois per month, preserving, at the same time, a normal appearance. This individual probably contains over 80 pounds of water, and it has endured temperatures of over 100° F. for many days with the relative humidity as low as 6 per cent. (See plate 3.)

The independence of entire individuals from a supply of water is also characteristic of the branches or members of the body of many succulents. Thus, the trunk of a great sahuaro (*Cereus giganteus*) will decay as a result of disease and the bare woody brown column will be seen with a normal green branch attached to it at a point 15 or 20 feet from the ground, in which position it may receive nothing from the soil.

In the effort to determine the physiological character of the storage tissues, large preparations were made by which cuttings of various species were inserted in or in contact with the water-containing tissues of plants with special mechanisms. Cactuses of various species were thus made parasitic on other

species without the accomplishment of grafting. More striking results, however, were obtained by the making of combinations whereby species of widely divergent morphological character were brought together. Thus, branches of *Opuntia versicolor* have been attached to *Fouquieria splendens* in such manner that they derived a water-supply from the enforced host that kept them alive for many months, while unattached branches withered and dried to dust. An African *Euphorbia* derived a similar supply from the sahuaro; *Cissus digitata* from southern Mexico was successfully implanted in the storage-tissues of *Opuntia, Echinocactus,* and *Cereus,* thriving especially when cuttings were inserted in the fleshy joints of the flat-jointed opuntias. Furthermore, the aerial roots of this form were capable of entering openings made in the epidermis of the succulent host and penetrating to some slight depth, the exact anatomical arrangement not yet having been determined. (Plate 3.)

All the facts at hand seem to point to the suggestion that the essential conditions underlying parasitism may be brought to light by a continuation of these tests, especially if a chemical examination of the sap of the forms which are successfully joined be made. The investigation will be pushed in this direction.

The determinations of volumetric changes occurring in succulents which have been carried on by Mrs. V. M. Spalding, will also be brought into this work, being of basal importance in certain features of the observations.

The Course of the Vegetative Seasons in Southern Arizona.—In the collations of the known facts as to the general botanical features of North American deserts a detailed study has been made by Dr. MacDougal of the seasonal activity of the vegetation of the Tucson region. Climatic conditions at the Desert Laboratory are such as to allow of the definition of seasons as follows: The winter wet season, extending from December to March; the arid fore-summer, from March to July; the humid midsummer, inclusive of July and August; the arid after-summer, extending through September to the latter part of November. The winter wet season witnesses the activity of a large number of plants which differ but little from the vegetation of moist regions, except in the fact that their seeds and shoots are capable of lying dormant during long dry seasons. The earlier forms perfect their reproductive organs about the first of February, after they have received 21,510 hour-degree Fahrenheit units of exposure to temperatures above the freezing-point, or more than five times as much as that which is required to bring the earlier plants, such as *Draba verna* of New York, to bloom. The heat exposure by the end of the wet winter season has now reached the total of 59,071 units by April 1, upon which the opuntias and the greater number of the cacti and succulents have formed flowers and quickly proceed with the formation of fruits. The beginning of the moist mid-summer witnesses the accumulation of 160,539 units of heat, and with the accession of the rains a wide vari-

ety of storage forms and true mesophytic species burst into bloom. Desert grasses, spiny shrubs, barrel-cacti, quickly moving annuals, and a wide variety of forms begin the formation of fruits which in most instances carry their maturing processes well into the arid after-summer, at the end of which time the total heat exposure for the year has reached the enormous total of 325,385 hour-degree units. The total precipitation for the year is about 12 inches. This region has probably had an arid climate at least since Pleistocene times, and the vegetation of the wet winter season may well consist of the lineal descendants of the original water-loving flora. The forms active at other seasons, however, must be of more recent origin, and must have originated within or near the present distribution pattern of the separate species. In some deserts but little xerophytic vegetation is known, the prevalent forms being those which are active only in the seasons of maximum precipitation.

COOPERATIVE ARRANGEMENTS.

The successful operation of a large number of plans for cooperation between members of the staff and other workers is to be recorded. In many instances effort and expenditure far beyond the customary exchange of courtesies with other institutions were involved.

Travel.—Mr. F. J. Johnson, of Chicago, furnished funds by means of which Dr. and Mrs. B. E. Livingston have spent the entire year in visiting various laboratories in Europe, for the purpose of examining apparatus, collecting literature, and carrying on extensive experiments at Munich, where ample facilities were placed at their disposal by Prof. K. Goebel, director of the botanical garden.

Chemical Analyses.—Prof. R. H. Forbes and Prof. H. H. Ross, in continuation of previous work, have made the annual detailed analysis of the water of the Salton Sea, together with various minor analyses, all of which have entailed lengthy attention.

Branch Laboratory at Carmel.—The Carmel Development Company has set aside a small building in Carmel, California, for the use of Dr. W. A. Cannon in the continuation of his work on the anatomy of hybrids. The fittings and equipment provided have made this one of the most efficient branch laboratories of the Department. The demonstration of the suitability of this locality for works in various lines during the summer months suggests the advisability of continuing this arrangement.

Material for Ecological Work.—The Department of Botany of the University of Kansas was given the use of the facilities of the Desert Laboratory for the purpose of securing photographs, anatomical material, and notes for work in ecology in that institution. Mr. L. M. Peace, assistant in botany, was in residence for the purpose in question during July and August, 1908.

Inheritance in Evening-primroses.—Mr. R. R. Gates, of the University of Chicago, was given some aid in the preparation of the illustrations for his work on heredity in the evening-primroses. Seeds and material of hybrid combinations made by Dr. MacDougal were turned over to him.

Floristics of the Chiricahua Mountains.—Mr. J. C. Blumer, who has acted as assistant at the Desert Laboratory during periods in 1907 and 1908, has completed his survey of the flora of the Chiricahua Mountains, in southeastern Arizona, and has distributed suites of preserved plants to many of the principal herbaria of the world. The privileges of the Laboratory were granted him for this purpose for several months in 1908.

Observers on Evaporating Power of the Air.—Mutually advantageous arrangements, whereby a series of standardized atmometers were put in the hands of observers in various parts of the continent, were made by Messrs. Livingston and Shreve. The fidelity, exactness, and sustained interest displayed in this investigation by all concerned render it a notably fine exhibition of contribution of individual effort to the obtaining of data for the solution of a general question. The following list includes the names of the cooperators and shows the distribution of the stations in atmometric investigations in 1908:

C. C. Jones, Fredericton, New Brunswick.
D. P. Penhallow, St. Andrews, New Brunswick.
Carleton J. Lynde, Macdonald College, Quebec.
W. J. Morse, Orono, Maine.
W. H. Alexander, Burlington, Vermont.
M. R. Sanford, Syracuse, New York.
B. M. Duggar, Ithaca, New York.
C. Stuart Gager, New York, New York.
M. T. Cook, Newark, Delaware.
Henry Shreve, Easton, Maryland.
Joseph E. Harned, Oakland, Maryland.
F. L. Stevens and J. C. Temple, West Raleigh, North Carolina.
C. D. Howe and Frederick Philippi, Pisgah Forest, North Carolina.
P. H. Rolfs and Wm. Hess, Gainesville, Florida.
Ernst A. Bessey, Miami, Florida.
Edith C. Bellamy, Florence, Alabama.
Samuel M. Bain, Knoxville, Tennessee.
Stephen R. Williams, Oxford, Ohio.
James Fisher, Houghton, Michigan.
Mrs. J. Carter, St. Helen, Michigan.
Jennie D. Livingston, Grand Rapids, Michigan.
George P. Burns, Ann Arbor, Michigan.
G. H. Jenson, Chicago, Illinois.
E. N. Transeau, Charleston, Illinois.
H. A. Gleason and J. T. Narrett, Urbana, Illinois.
Frank Allen, Winnipeg, Manitoba.
F. E. Clements and Carl P. Hartley, Minneapolis, Minnesota.
E. Shimek, Iowa City, Iowa.
William Trelease and Henri Hus, St. Louis, Missouri.
L. R. Carey, Cameron, Louisiana.
L. R. Waldron, Dickson, North Dakota.
George A. Loveland, Lincoln, Nebraska.
W. W. Burr, North Platte, Nebraska.
John F. Nicholson, Stillwater, Oklahoma.
F. L. Kennard, Dalhart, Texas.
W. L. Bray, Austin, Texas.
T. N. Willing and G. A. Charlton, Regina, Saskatchewan.
Charles H. Shaw, Rogers Pass, British Columbia.
Deane B. Swingle, Bozeman, Montana.
J. E. Church, Jr., Reno, Nevada.
Aven Nelson, Laramie, Wyoming.
Francis Ramaley, Boulder, Colorado.
Ira D. Cardiff and A. O. Garret, Salt Lake City, Utah.
W. B. McCallum, Tucson, Arizona.
T. C. Frye, Seattle, Washington.
Thomas A. Bonser, Spokane, Washington.
Albert R. Sweetser, Eugene, Oregon.
George J. Peirce, Palo Alto, California.
Ford Ashman Carpenter and Archibald Campbell, San Diego, California.
B. G. Johnson, Mecca, California.

The Cactaceæ.—The facilities of the Desert Laboratory were granted to Dr. J. N. Rose, of the Smithsonian Institution, for an investigation of the Cactaceæ of southern Arizona. In accordance with this arrangement transportation and field equipment were furnished Dr. Rose during April and May, by which he was able to make explorations, collections, and field observations in western Texas, New Mexico, Arizona, and southern California. A large amount of material was secured by which many questions as to habit and relationship in this important group may be answered.

The Geology of the Tucson Region.—Dr. W. P. Blake, Territorial geologist of Arizona, by special request, has compiled the results of his observations on the physiography and geology of the Tucson region during the last 18 years. This material constitutes a special section of publication 99, recently issued. The treatment of such phases of the subject as the origin of the slopes, soils, former lacustrine conditions, changes in climate, submergence, and elevation, together with the map of the region during the Post-pliocene period, makes this contribution of great and enduring value to workers in all branches of natural history, as well as being of great popular interest. An area of nearly 2,000 square miles is critically treated in this paper.

Heredity in the Chrysomelid Beetles.—Dr. W. L. Tower, in the continuation of his extensive researches on the influence of climatic factors upon the organic processes most directly concerned in the evolution of organisms, which have been carried on in Mexico for several years, has placed a series of cultures at the Desert Laboratory. The conditions here afford opportunities for testing the total effect of the factors of the Tucson desert upon organisms from a widely distant locality, and of analyzing these effects.

Two series of experiments were begun in the current year for obtaining evidence upon problems as follows:

(1) The action of the combined physical environment upon organisms that are transported into an entirely new habitat and removed from the organic factors, such as the food and organic enemies questions. Four different series of cultures were started under this general head and three of them have thus far succeeded beyond the fondest expectations, while one failed entirely.

(2) The action of changed physical conditions of existence upon particular organic processes that are of importance in evolution. Under this head one set of experiments was started in June and has thus far given every promise of exact and conclusive data upon the problems under consideration.

Vivaria inclosed by close-meshed wire-netting have been constructed, in which the natural food plants and pure strains of beetles have been placed.

The results of the first season warrant the extension and enlargement of these cultures.

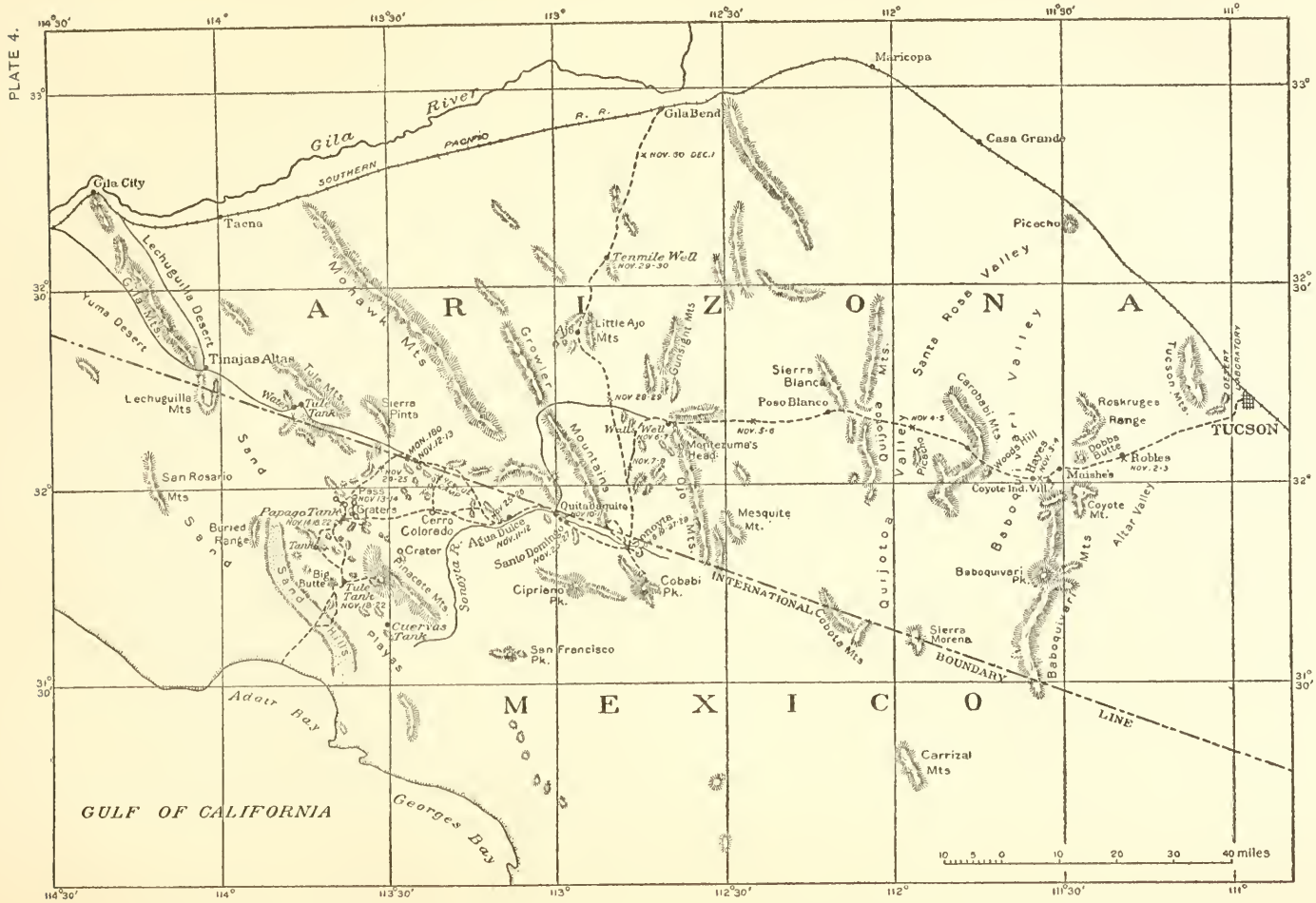
The Lichens of the Desert Laboratory Domain.—In connection with Professor Spalding's work on distribution, Prof. Bruce Fink, of Miami University, has made a critical analysis of the lichen flora of the vicinity of the Desert Laboratory. Thirty-two species, representing 15 genera, a few of which had not been previously known, were found. All were found to exhibit structures suitable for endurance of low humidities, the action of wind, and of insolation of high intensity. The presumptive evidence points to the conclusion that these plants may absorb water vapor from the air.

The Flora of the Tucson Region.—Prof. J. J. Thornber, of the University of Arizona, has made an exhaustive determination of the seed-plants of the region covered by Professor Spalding's investigations in plant distribution. Among the more important generalizations made apparent by his work it is to be cited that the flora of this portion of the desert consists of winter and summer annual herbs to the extent of 43 per cent, of perennial herbs to the extent of 22.6 per cent, the remaining 24.4 per cent being woody perennials. Nearly half of the introduced species behave as winter annuals, and are from the Mediterranean region. Sixty-eight families, represented by 269 genera and 449 species, were formed, of which 22 genera were introduced by man.

The Geology of Tumamoc Hill.—In connection with Professor Spalding's studies in distribution, Prof. C. F. Tolman, of the University of Arizona, has made an exact analysis of the geological features of the three low basaltic hills on one of which the Desert Laboratory stands, and of the adjacent slopes in the domain. Professor Tolman has given some consideration to the modifications of geological processes and deposits induced by aridity. In addition the petrography of the principal rock-formations has been made out. The entire mass of information presented will be invaluable in all investigations dealing with habitats and distribution in this locality.

Topographic and Bio-geographic Features of the Pinacate Region.—Tucson, the site of the Desert Laboratory, is situated near the crest of a great flattish ridge that extends from eastern Arizona to the Colorado River and the Gulf of California. The naturalists of the Mexican Boundary Survey traversed the southern slope of this ridge, but attention was chiefly given to a narrow zone and no connected information as to the region existed. It was deemed important that a traverse be made from the Desert Laboratory direct to the shores of the Gulf of California, and note made of the principal facts and conditions attendant upon the merging of this elevated desert with that of the coastal area of the Pacific. To this end an expedition, including among its members Dr. W. T. Hornaday, Director of the New York Zoological Park, Hon. J. M. Phillips, Game Commissioner of Pennsylvania, Mr. G.

PLATE 4.



SKETCH MAP SHOWING ROUTE OF EXPEDITION FROM DESERT LABORATORY TO PINACATE MOUNTAINS AND THE GULF OF CALIFORNIA.

Sykes, and Dr. D. T. MacDougal, of the Desert Laboratory, was organized to make a survey of the region in question. A field outfit was drawn from the equipment of the Desert Laboratory, and Messrs. Hornaday and Phillips contributed a sum in cash equal to half of the field expenses, which were not inconsiderable. The route traversed followed due west from Tucson for more than a hundred miles, then due south across the International boundary at Monument 167. By the intervention of President Roosevelt and Hon. Elihu Root, the expedition was given clearance on its material by the Mexican government and a detail of the fiscal guard marched over a hundred miles to receive and safeguard the entrance of the party. The known routes of travel were left at Monument 180 west of Sonoyta, and from thence the party in various detachments went due south around the Pinacate group of volcanoes and to the shores of Adair Bay.

The height of the Cobabi Peak, near Sonoyta, was reduced from 9,425 feet, as given on maps of the U. S. Hydrographic Survey, to 4,325 feet, and the position of the principal topographic features were plotted by Mr. Sykes.

The Pinacate Mountains were found to include an oval mass of volcanic cones and lava beds about 40 miles in length and parallel to the axis of the Gulf near Adair Bay. The culminating peak was climbed for the first time and its elevation fixed at 4,300 feet by carefully corrected aneroids. Over 200 volcanic cones are visible from its summit, many of which had fairly perfect craters. In addition, many sunken craters were found, some of which were of great depth and size. One, designated as Sykes Crater, has a depth of 750 feet and a diameter of 2,000 feet. The floors of these craters bore an abundant vegetation. Among other important facts the Canada mountain-sheep (*Ovis canadensis*) was found here in great abundance, sometimes living in these deep craters, but little above the sea-level in altitude.

It was found also that some of the plants of the Tucson region, including the sahuaro (*Cereus giganteus*), creosote-bush (*Covillea tridentata*), *Encelia farinosa,* cholla (*Opuntia fulgida*), and a few others, actually descend to nearly sea-level, thus showing a vertical range of 4,000 feet and covering several degrees of latitude. The botanical facts obtained will not only be valuable when correlated with the results of detailed surveys being made in the Tucson region, but will also have a direct bearing upon some phases of the acclimatization experiments.

The contact of desert and littoral in this region brings about some highly interesting topographical and biological features. A great ridge of dunes a few miles in width and in places 80 to 100 feet in height has been formed 6 to 8 miles from the shore and roughly parallel to it. Between this and the salt water runs a great level stretch of tall galleta grass and halophytes. The dunes themselves bear a strictly desert vegetation. The streamways from the

mountain slopes come down to the dunes and in time of precipitation carry their torrential floods directly against the sand embankment, where they spread out and make great level playas with a characteristic vegetation.

THE STAFF.

Dr. Forrest Shreve, Professor of Biology in the Woman's College of Baltimore, has been added to the staff, his appointment dating from May 1, 1908, Dr. Shreve has just completed the compilation of his survey of the plants of Maryland, and will take up some special problems of the same nature with regard to desert vegetation. Dr. B. E. Livingston was given leave of absence at the beginning of the year and has visited a number of laboratories in Europe in which investigations on physical physiology were being carried on. The greater part of the year was spent in the botanical garden at Munich, on some experimental investigations on relative transpiration. The Department is indebted to the director, Prof. K. Goebel, for the privileges granted and facilities provided for Dr. Livingston's work during his stay.

Dr. W. A. Cannon resided, May to September inclusive, at Carmel, California, where he was provided with laboratory facilities by the Carmel Development Company. The location in question furnished conditions suitable for work on the anatomy of hybrids and also for participation in the examination of Mr. Burbank's plants. The remainder of the staff have chiefly centered their effort during the year, on work at the Desert Laboratory.

EQUIPMENT.

Shop.—A stone building 40 by 20 feet has been erected at the foot of Tumamoc Hill, directly below the Laboratory, after designs by Mr. G. Sykes. The walls are of stone, brick lined, the floor of extra rigidity, and the illumination designed especially with regard to the use of the apparatus and tools with which it is furnished. The roof is of shingles, furnished with the ventilating ridge roll which has been found so efficient in other buildings of the Laboratory. A full complement of carpenter's and cabinetmaker's tools, lathe, drill-press, band-saw, planer, forge, grinding-wheels, etc., with fittings, have been put in place, and separate motors have been fitted to the larger tools, current being secured from a power line leading to the Laboratory.

Vivaria and Plant Shelters.—A shelter for the culture of introduced plants has been constructed in the experimental grounds at the base of Tumamoc Hill. This consists of a flat-topped skeleton frame with the walls and roof of lath, placed to cover half of the space. Six vivaria, 6 by 6 by 4 feet, inclosed by fine wire screens, have been made and set in position in the experimental grounds. These are devoted exclusively to the climatic experiments with beetles carried on for Prof. W. L. Tower. Pipe-lines have been extended to the various parts of the domain, including the experimental grounds.

Laboratory and Office.—A small number of volumes have been added to the working collection of books. A few minor pieces of apparatus and furniture have been purchased.

REPAIRS.

The 6 miles of fencing on the domain and around the separate experimental plantations has been thoroughly overhauled and put into good condition. The woodwork of the Desert Laboratory, including the roofs as well as the smaller buildings, has been painted. Apparatus and tools of all kinds, pack equipment, camp outfits, and vehicles have been repaired from time to time. The completion of the shop will materially lessen the expenses under this heading.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

CARROLL D. WRIGHT, DIRECTOR.

The work of this Department is progressing satisfactorily. It is necessarily slow, on account of the difficulty in securing original material from which to form conclusions as to the general economic development of the United States.

The title of the work as agreed upon by the collaborators, and as approved by the Executive Committee, is "Contributions to American economic history." It is believed that this is a truer and more adequate title than that which has been used, "Economic history of the United States"; for the purpose is not so much to write a literary economic history as to furnish the materials in general chronological and logical order for such a history. This was the intention from the first, but the adoption of a satisfactory title has been recent.

At present this Department is employing 204 different individuals, including the collaborators, in the collection of material. It is very evident now that the work can be completed with the appropriations already made; certainly there will not be needed a very large addition to those appropriations. As the work approaches completion I am able to give a more general idea of its nature than has been given in previous reports.

DIVISION I.—POPULATION AND IMMIGRATION.

The work of this division, under the direction of Dr. Walter F. Willcox, of Cornell University, it now appears, will group itself in the end about one fundamental position—the increase of population in the United States and the part that immigration has played in that increase and its influence upon our economic development. As Dr. Willcox regards it, the central theme of modern history is not the growth of liberty or the spread of democratic institutions, but rather the expansion of the white race; or, to use the more definite geographical term, the real expansion of Europe. It is in its relation to this movement that the economic progress of the United States finds its meaning. There are nearly as many Europeans now living outside of Europe as there were living in Europe when America was discovered, and two-thirds of them are in the United States. The number of Europeans by blood has quadrupled in the last century and a half, while the racial stocks which have not been vivified by the touch of Europe have dwindled in numbers and in power. The whole world is thus becoming more and more Europe writ large, but in

* Address: Clark College, Worcester, Massachusetts. Grant No. 474. $30,000 for investigations relative to an economic history of the United States. (For previous reports see Year Books Nos. 3, 4, 5, and 6.)

the process Europe itself is being transformed. The reaction of this process as a whole, and of the United States as its dominant factor, upon Europe is one of the most important and at the same time elusive elements in the history. With the increase in amount and complexity of European immigration into the United States this country must become more representative of the parent stocks. As Mr. Bryce said years ago, "Europe now stretches to the Mississippi River," so it may soon be said "Europe now stretches to the Pacific." Certainly there is much evidence that the two regions are growing more and more alike each year, and hence the importance of the movement of immigration in the economic development of this country.

There is no convincing reason for holding that the rapid influx of immigrants has materially checked the increase of the native population, or that the instinctive economic tendencies of the foreign-born population differ fundamentally or permanently from those of the natives. How far general conclusions like these to which Dr. Willcox's studies have slowly brought him will serve as unifying threads in that particular work it is hard to say, but they seem clear and important enough to deserve mention in his report of progress. They have been argued in a preliminary way in his two papers—"The expansion of Europe" and "The distribution of immigrants."

The persons now engaged in this division are:

Mrs. Mary Roberts Coolidge: "History of Chinese immigration to the United States." Copy is in hand and negotiations for its private publication are being made.
H. P. Fairchild: Work on Greek immigration.
Prof. A. B. Faust: "Germans in the United States," a copy of the final report being in hand. The original has received the first prize of $3,000 in a competition and will soon be printed by the University of Chicago.
Dr. E. A. Goldenweiser: "Doctor's thesis on Russian immigration to the United States." Copy now in hand, but not yet published.
Mrs. L. S. Houghton: "The economic status of Syrians in the United States." Manuscript in hand.
H. M. Lewis: "Summary of the decisions affecting Chinese immigration to the United States." Manuscript in hand.

It will thus be seen that Dr. Willcox has a large amount of material all ready for printing, either by private enterprise or as a part of his final report on Population and Immigration.

Division 2.—Agriculture and Forestry.

The experts in this Department are hard at work, and President Kenyon L. Butterfield, in charge, feels more encouraged about the outlook than at any time since it began. It is a large field that he has undertaken, but the quantity of work being done, as shown by his report, is very satisfactory.

Prof. B. H. Hibbard, who is at work on the Federal and State land policies as influential in economic development, reports that studies have been made of North and South Dakota, by John L. Coulter, of the University of Wisconsin; Colorado, by L. F. Smith, a student in the University of Colorado; Oregon, by F. G. Young; Iowa, by Professor Hibbard himself.

The more extensive part of his work is on the Federal land policy, and in this he has collected a large amount of material.

Mr. Jesse E. Pope, of New Jersey, is also at work, under the direction of President Butterfield, while Mr. George F. Wells, of Vermont, has already brought out the following works:

Church federation in Vermont. (First Annual Report Executive Committee of Inter-Church Conference on Federation, 81 Bible House, New York, New York, January 1, 1907.)
An answer to the New England country-church question. (Bibliotheca Sacra, April, 1907.)
What our country churches need. (Methodist Review, July, 1907.)
The country church and the making of manhood. (Homiletic Review, August, 1907.)

Mr. Wells also has a body of material at hand and available for final report.

Prof. H. C. Taylor, of Wisconsin, as the result of his studies of the history of agricultural production and forms of land tenure, has the following monographs, which have been prepared under his direction:

Land tenure in Mississippi, by Alex. Cance.
Land tenure in the wheat region of the Northwest, by John L. Coulter.
Land tenure in Oregon, by Louis L. Swift.
Land tenure in Minnesota, by Wilber Holcomb.
Land tenure in Wisconsin, by Henry C. Taylor.
A history of the dairy industry in the township of Windsor, Wisconsin, by C. W. Dodge.
A history of the dairy industry in Sauk County, Wisconsin, by Riley Stone.
The swine industry in the United States since 1840, by John L. Tormey.
The wheat industry in Wisconsin, by J. G. Thompson (in press).
Industrial history of the Red River Valley, by John L. Coulter (will be printed soon).
The agricultural history of Brown County, Minnesota (including the history of the New Ulm German colony), by John L. Coulter.
The Minneapolis market and the wheat region of the Northwest, by William Kuntz.
The problem of the nation's forests, by W. S. Tower.

The following are also in preparation:

History of the agricultural production since 1840, by John L. Coulter.
Land tenure in the South; also cane sugar industry, by Alex. Cance.
Agriculture in New England, by J. C. Marquis.

Eight of these have been turned in, some of which are well prepared, and three of which will be published soon.

Five monographs on land tenure have been completed, and a large mass of material collected and classified with prospect of early completion.

Mr. Edward D. Jones, of the University of Michigan, is collecting a variety of material and has associated with him those named below with the following assigned subjects:

Marketing Texas cattle via the Kansas Trail, 1870–1883: Milton Everett.
History of Illinois Grain Dealers' Association: S. W. Strong.
Reforms in marketing Territory wools: Dallas J. Osborne.
Development of agricultural interests in western New York since 1840: Rich L. Selden.
History of marketing around Sheridan, Indiana: J. P. Davis.
History of agricultural marketing in southern New England: J. Clyde Marquis.
History of Grain Dealers' National Association: John F. Courcier.
Cooperative marketing in Iowa: C. G. Messerol.

History of agricultural cooperation in California: Lewis A. McArthur.
History of agricultural marketing in Florida: E. O. Painter.
History of agriculture in Ohio: Ernest J. Riggs.
History of the Raisin Growers' Association: George Robertson.
History of Iowa dairy industry: H. E. Colby.
Maryland tobacco markets: Richard S. Hill.
History of the Ozark Fruit Growers' Association: G. A. Atwood.

The number of persons now engaged in this division is 33.

Division 3.—Mining.

Mr. Edward W. Parker, in submitting his report of progress on the history of mining industry, states that during the year actual progress has been made by the different experts to whom the preparation of the histories of the different subjects had been committed. At the time of making the last annual report manuscripts had been completed as follows:

Cement, gypsum, and magnetite, by Mr. Edwin C. Eckel, of the U. S. Geological Survey.
Petroleum and natural gas, by Prof. George P. Grimsley, of the Geological Survey of West Virginia.
Bituminous coal, by Prof. W. S. Landis, of Lehigh University.
Anthracite coal, by Mr. Henry H. Stoek, of Scranton, Pennsylvania.

Recently Mr. Walter R. Ingalls has completed his histories on lead and zinc, and these have been published as a separate volume. Prior to this Mr. Ingalls had published, in the Transactions of the American Institute of Mining Engineers, a chronology of lead mining (vol. xxxviii, 1907).

A history of gold and silver, by Prof. Walter R. Crane, of the Columbia University School of Mines, New York, has been completed and published as a separate volume. This private and advance publication of Professor Crane contains some material which it will be necessary to eliminate for the Carnegie Institution publications, but other portions of it will appear in such publications in a condensed form.

The history of the clay-working industry, by Prof. Heinrich Ries, of Cornell University, has been received, but is not yet published.

The history of the copper-mining industry was originally confided to Dr. M. M. Bolles, of Columbia University. Dr. Bolles was obliged to withdraw from this work, and it was then confided to Mr. L. C. Graton, of the U. S. Geological Survey. Mr. Graton has already collected and assembled much material for the complete manuscript. The material already collected relates principally to the history of production and producing sources and to the development of methods of production. Mr. Graton has procured some important original data concerning attempts to form copper monopolies, such as the Scranton "corner"; also a considerable amount of new information about prices and uses.

Prof. Charles E. Munroe, of the George Washington University, having charge of the work on chemical mineral industries, will be able to present his complete manuscript by the end of the present calendar year.

Prof. B. F. Laney, of the University of North Carolina, is making strenuous efforts to complete his work on the stone-quarrying industry by next June.

Dr. Joseph Hyde Pratt, also of the University of North Carolina, will have his work on precious stones, rare earths, and abrasive materials ready by next June.

Mr. William E. Colby, of San Francisco, at work on mining law, will also be able to present his completed manuscript during the next 12 months.

Dr. David T. Day, of the U. S. Geological Survey, who is at work on quicksilver, platinum, antimony, etc., has his work well advanced and expects to hand in the manuscript on platinum and its associated mineral, iridium, and also the manuscript of his other subjects, by the end of the present calendar year.

Prof. C. K. Leith, through his assistant, Mr. Holden, has substantially completed the correlation of his detailed information for the Southern States on iron ores.

Professor Williams, of the Iowa State College, is working on the history of graphite, and his work will be completed during the next 8 or 9 months.

Under Mr. Parker's direction there are 18 persons employed.

Division 4.—Manufactures.

Dr. Victor S. Clark, in charge, has 6 assistants, as follows:

Prof. M. B. Hammond, of Ohio State University, is engaged upon original research into the history of American cotton manufacturing.

Prof. John B. Phillips, of the Colorado State University, has a manuscript nearly ready on manufactures in the Mountain States.

Mr. E. A. Riley is writing the history of manufactures in Chicago, and his complete manuscript is expected toward the end of the year.

Mr. L. Lippincott, writing on the manufactures in the central Mississippi Valley, has nearly completed his work.

Mr. R. L. Douglass, of Kansas University, is making an investigation of manufactures in the Prairie States.

Mr. Charles Klein, of Berkeley, California, is collecting data concerning manufactures, early and recent, in southern California, and his manuscript promises to be very valuable indeed.

Dr. Clark himself has spent some weeks in getting out some very important original English material relating to the development of manufactures during the Colonial period. He reports that nothing has yet been published relating to manufactures, the plan upon which he is working contemplating leaving monographs in the hands of authors until the latest possible moment. The number of his assistants is 6.

DIVISION 5.—TRANSPORTATION.

Prof. B. H. Meyer, of the University of Wisconsin, makes a very satisfactory report of the progress of work under him during the past year. The studies completed and already published are as follows:

The State works of Pennsylvania, by A. L. Bishop. (Connecticut Academy of Arts and Sciences, 1907.)
Railroad reorganization, by Stuart Daggett. (Houghton, Mifflin & Co., 1908.)
Congressional history of railways, vol. 1, by Lewis H. Haney. (University of Wisconsin, 1908.)
Anthracite tide-water canals, by Chester L. Jones. (University of Pennsylvania, 1908.)
Transportation in the antebellum South; an economic analysis, by U. B. Phillips. (Quarterly Journal of Economics, May, 1905.)
An American State-owned railroad (the Western and Atlantic), by U. B. Phillips. (Yale Review, November, 1906.)
A history of transportation in the eastern cotton belt to 1860, by U. B. Phillips. (The Columbia University Press (Macmillan Company), 1908.)
The trunk-line rate system; a distance tariff, by W. Z. Ripley. (Quarterly Journal of Economics, vol. 20, 1906, reprinted in Ripley Railway Problems (Ginn & Co.), 1907.)
Private freight cars and American railways, by L. D. H. Weld. (Columbia University Studies (Longmans, Green & Co.), 1908.)

The studies enumerated below are completed, but not yet published:

Railway pooling, by Alton D. Adams.
Financial history of railroads, vol. 1, by F. A. Cleveland.
Railroad accidents, by Carroll W. Doten.
Congressional history of railways, vol. 2, by Lewis H. Haney.
Atlantic tide-water canals, by Geo. D. Luetscher.
Railway transportation in Texas, by C. S. Potts.
History of navigation on the lower Mississippi, by R. B. Way.

The studies still uncompleted are:

History of the Illinois Central Railroad: H. G. Brownson.
History of the Granger movement: Solon J. Buck.
Financial history of railroads, vol. 2: F. A. Cleveland.
Railway transportation in Ohio: W. F. Gephart.
Canadian railways in their relation to railways in the United States: S. L. McLean.
Transportation in the western cotton belt: U. B. Phillips.
History of transportation on the Great Lakes: Geo. G. Tunnell.
The development of transportation in California and the growth of the transcontinental business: A. A. Young.
Development of transportation in the Pacific Northwest: F. G. Young.

Some of these uncompleted studies will probably be finished before this report can be furnished, while others will probably consume the greater part of 1909, if not the entire year. A year ago it seemed reasonably certain that the manuscripts of all these studies would be completed by September of this year, but unforeseen circumstances have made it impossible for a number of Professor Meyer's assistants to carry out their plans. They have all of them been working to the best of their ability and in good faith, and it may be September 1, 1909, therefore, before all these special studies can be turned in.

The Division of Transportation, as reported, has published the series of studies enumerated above, and it holds the completed manuscripts under the

second list of manuscripts completed but not published. It has collected all the material previous to 1850, and is in a position to commence the preparation of the final volumes as soon as the most important of the unfinished manuscripts have been turned in.

Dr. Meyer feels that several special studies might be undertaken with very great benefit to the work of the division and the Department, provided more money than can be spared him could be appropriated. This difficulty, however, can probably be met by a redivision of the allotments.

There are at work as associates of Professor Meyer 9 assistants.

Division 6.—Domestic and Foreign Commerce.

Prof. Emory R. Johnson, of the University of Pennsylvania, in charge of this division, reports that his assistants on the subject of domestic and foreign commerce have made satisfactory progress. Dr. J. Russell Smith has completed his study on the History of the Organization of Ocean Commerce, and his work, somewhat enlarged, has been published serially in the Railway Age-Gazette, under the title of "The ocean carrier." This work will soon appear in book form.

Mr. Raymond McFarland, of Worcester, Massachusetts, and Dr. Walter Sheldon Tower, of the University of Pennsylvania, have completed a monograph on the History of American Fisheries. Their work, together with Dr. Tower's monograph on the History of the Whale Fisheries of the United States, published by the University of Pennsylvania, covers the entire field of the economic history of American fisheries.

Dr. G. G. Huebner has devoted a large part of his time during the past year to work on the History of the Foreign Trade of the United States, and has nearly completed the first draft of his work. His manuscript is practically finished, and needs only final revision.

Dr. Thomas Conway, Jr., has been at work on the History of the Coastwise Commerce of the United States. He began his work over three years ago, and it is still incomplete on account of his inability to give a larger amount of time to his investigations, but he hopes to be able to finish the work the present calendar year.

Dr. A. A. Giesecke continues his work on the History of American Commercial Policy. The section of this work dealing with the Colonial period has been thoroughly revised and rewritten and was accepted as a doctor's thesis at Cornell University last June.

The Commercial Policy of the United States since 1789 will take some time to complete, and it may be a full year before it reaches completion.

The number of assistants at work with Professor Johnson is 7.

Division 7.—Money and Banking.

Dr. Davis R. Dewey, in charge, reports that since his report of a year ago he has been much encouraged by the progress of his investigations on the subject of banking and money, a very difficult subject, especially so far as securing the right kind of men to make original research is concerned. He has now been able to secure several new coworkers, who are prosecuting their researches with zeal, and a number of manuscripts have been finished or are promised at a very early date. This is a very encouraging future, in view of the embarrassments already alluded to in securing men. Dr. Dewey is obliged for many things to wait for the completion of the index which is being so admirably compiled by Miss Hasse. He has the assistance of 28 men, as follows:

Relation of the Treasury to the New York Money Market, J. W. Crook.
Study of local banking in Indiana, E. H. Davis.
History of banking in Minnesota, A. O. Eliason.
History of the national banking system, G. D. Hancock.
History of banking in Wisconsin, R. H. Hess.
History of banking in Ohio, C. C. Huntington.
History of banking in Iowa, I. A. Loos.
History of banking in California, R. Lowry.
Relation of the crop movement to the money market in the West, F. L. McVey.
History of banking in New Hampshire, W. M. Persons.
Bank and trust company legislation, J. B. Phillips.
History of banking in Missouri, J. E. Pope (J. R. Cole).
History of the Greenback movement in Iowa and the Northwest, C. O. Ruggles.
History of banking in North Carolina, C. L. Raper.
History of banking in Alabama, W. C. Scroggs.
History of banking in Tennessee, St. G. L. Sioussat.
History of banking in Illinois, R. J. Sprague.
Greenback party in Maine, D. L. Wing.
Banking in Indiana, R. M. Milburn.
Banking in Louisiana, T. H. Jacob.
Banking in Kentucky, E. C. Griffith.
Banking in Oregon, J. H. Gilbert.

Manuscripts on the following subjects have been completed:

History of banking in Pennsylvania, by J. T. Holdsworth.
History of banking in Kansas, by W. H. Isely.
Relation of depreciation of greenbacks to prices and wages, by W. C. Mitchell.
History of banking in Oklahoma, by S. Parlette.
Savings banks in Connecticut, by E. M. Peck.
History of banking in Florida, by D. Y. Thomas.

Division 8.—Labor Movement.

This division is under the charge of the Director of the Department of Economics and Sociology. Nearly all the material for the final volumes has been collected and the published results so far are:

The history of the industrial employment of women in the United States, by Miss Edith Abbott. (Journal of Political Economy, October, 1906.)
Harriet Martineau and the field of employment for women in 1836, by the same author. (Journal of Political Economy, December, 1906.)
Employment of women in cigar-making; history and present tendencies, by the same author. (Journal of Political Economy, January, 1907.)
The early history of child labor in America, by the same author. (American Journal of Sociology, July, 1908.)
Women in the cotton mills; a study in economic history, by the same author. (Journal of Political Economy, November, 1908.)

Completed manuscripts have been received from Hon. Charles F. Pidgin, late chief of the Massachusetts Bureau of Statistics of Labor, on "Average wages previous to 1860 and from 1860 to 1906, in forty leading occupations." Also from Dr. William H. Tolman, on the "Influence of industrial betterment as an economic factor."

With the aid of this division there has appeared a Bibliography of American trade-union publications.

Under this division it was reported last year that 2 volumes of "Labor history of the United States" had been completed and would be published. A serious obstacle arose to such publication and it has been deferred. There are now 5 volumes of labor history in the United States completed. The work has been done in cooperation with the University of Wisconsin and the American Bureau of Industrial Research, under the direction of Dr. Richard T. Ely and Prof. J. R. Commons. A condensed work of these 5 volumes is being prepared by Professor Commons for this division.

There are 7 persons at present aiding the Director in his division.

Division 9.—Industrial Organization.

Prof. J. W. Jenks, of Cornell University, in charge, reports that Professors Wilgus and Whittlesey have been employed on special monographic reports, the others gathering material largely from statutes and other sources.

Prof. Horace L. Wilgus, of Ann Arbor, is writing a history of corporation law in the United States and its influence upon economic development. He has had two graduate law-students assisting him, Mr. Robert N. Denham, Jr., and Mr. Carleton H. Woodward; also Miss I. S. Fredlund. Professor Jenks has also collected material along the line of Professor Wilgus's investigations through his own studies.

Mr. Walter L. Whittlesey, of Princeton University, is engaged upon the history of the lighting corporations in New York City, with special reference to noting and explaining the development of the organization of such public-service corporations. He has already covered a good part of the early field and expects to make a complete monograph suitable for publication. He practically devoted his entire time the past summer to the study.

Mr. Alfred H. Stone, in connection with his study of the negro in the United States, is making a special study of the changes in business organization brought about by the freeing of the negroes in the South, and also of the varying forms of business organization of the negroes as compared with the whites engaged in similar occupations, especially in agricultural work on the cotton plantations in the South.

Miss Alice Durand, of New York City, Miss Muriel Fessenden, of Ontario, Mrs. Ida R. Weed, of Washington, District of Columbia, Miss Bertha Griffin, of Philadelphia, and Mr. John Lapp, Cornell University, have been working at different times during the year in gathering material under Professor

Jenks's immediate supervision. None of the work under this division has been published.

The number of persons engaged on that work during the past year is 11.

DIVISION 10.—SOCIAL LEGISLATION.

Prof. Henry W. Farnam, Yale University, in charge of this division, informs the Director of the Department that since the report made last spring the following monographs have been completed and are now in hand:

Factory legislation of Rhode Island, by John Ker Towles, Ph. D.
The origin of the population of the South, by Prof. G. W. Dyer.
The administration of public poor relief in Wisconsin, by Thomas Crafer.
Trade unions and the law in Wisconsin, by Thomas Crafer.
The mining laws of Ohio, Indiana, and Illinois, by Nathan T. Isaacs, M. A.

Professor Farnam also reports that the monograph on the "Labor legislation of Kansas," by S. E. W. Bedford, is practically finished and is now being revised by the author.

An outline of an unfinished monograph, by H. Wirt Steele, on the "Labor laws of Maryland." has been published in the Johns Hopkins University Circular for May, 1908.

During the past year Professor Farnam has been absent in Europe, and Dr. Clive Day, of Yale University, took charge of the general work of the division. Professor Farnam desires to record his appreciation of the fidelity and judgment with which Dr. Day accomplished his task. Dr. Day is preparing a study of the social legislation of the Colonial period, which is to form an introductory section to the volume on social legislation of the United States.

Monographs originating in this division which have been published are:

Trade unions and the law in New York, by George G. Groat, Ph. D. (Columbia University Studies.)
History of labor legislation in New York, by Fred R. Fairchild, Ph. D. (Pub. Am. Economic Association, 1905.)
Factory legislation in Pennsylvania, by J. Lynn Barnard, Ph. D. (Vol. 19, Pub. Univ. of Penna., 1907.)

The following persons are still at work under Prof. Farnam's direction:

The labor legislation of Indiana: Charles F. Austin.
Recent labor legislation in Massachusetts: Prof. F. S. Baldwin.
The labor legislation of Kansas: S. E. W. Bedford.
Educational land grants of Wisconsin, North and South Dakota: John L. Coulter.
Social legislation of the Colonies: Prof. Clive Day.
The labor legislation of Iowa: E. H. Downey.
The mountain whites and social legislation: Prof. G. W. Dyer.
The labor legislation of California: Miss Lucile Eaves.
The labor legislation of New Jersey: Arthur S. Field.
The poor law of Ohio: Prof. J. E. Hagerty.
Land legislation of Texas: R. McKitrick.
The mining laws of Pennsylvania: Blaine F. Moore.
The labor legislation of Michigan: Carl E. Parry.
Social legislation in the Southern States: D. L. Peacock.
The poor law and public relief in Missouri: Prof. T. J. Riley.
The labor legislation of Maryland: H. Wirt Steele.
The labor legislation of Rhode Island: John K. Towles.
Homestead and exemption laws in the Northern States: Prof. J. H. Underwood.
Anti-trust legislation in Wisconsin, Nebraska, Iowa, and Minnesota: C. L. Waldron.

There are now 19 persons engaged in this division.

Division 11.—Federal and State Finance, including Taxation.

This division, under the charge of Prof. Henry B. Gardner, of Brown University, reports good progress and the following list of men who have undertaken work in the division. The works already published are:

Financial history of Maryland, 1789–1848, by H. S. Hanna, Ph. D. (Pub. in Johns Hopkins Univ. Studies in Historical and Political Science, series xxv, Nos. 8, 9, 10.)
Financial history of Milwaukee, by Prof. L. M. Larson. (Pub. in Bulletin of the Univ. of Wis. Econ. and Polit. Science series, vol. iv, No. 2.)
Financial history of Wisconsin, by Prof. R. V. Phelan, Ph. D. (Pub. in Bul. of the Univ. of Wis. Econ. and Polit. Sci. series, vol. ii, No. 2.)
The finances of Cleveland, by Prof. C. C. Williamson, Ph. D. (Pub. in the Columbia Studies in Hist. Econ. and Pub. Law, vol. xxv, No. 3.)
Financial history of Oregon, by Prof. F. G. Young, Ph. D. (Some chapters completed and published in the Quarterly of the Oregon Hist. Society, vol. vii, No. 4, pp. 360–432, and vol. viii, No. 2, pp. 129–190.)

The completed but not published studies are:

Financial history of North Dakota, by Prof. J. E. Boyle, Ph. D.
Financial history of Topeka, Kansas, by Prof. J. E. Boyle, Ph. D.
Financial history of Montana, by G. G. Bechtel.
Financial history of Colorado, by J. W. Ellison.
Financial history of Georgia, by Miss Julia A. Flisch.

The following studies are well along towards completion, but are not as yet finished:

Financial history of California, by Prof. C. C. Phlenn, Ph. D.
Financial history of Alabama, by W. O. Scroggs.
Financial history of Ohio, by Prof. E. L. Bogart, Ph. D.
Financial history of Texas, by E. T. Miller.
Financial history of Tennessee, by Prof. St. G. L. Sioussat.
Financial history of Virginia, by E. M. Sydenstricker.
Financial history of Vermont, by Fred'k Albord, Ph. D.
Financial history of South Carolina, by Geo. McCutchen.
Financial history of Iowa, by Prof. F. L. Herriott.
Financial history of Louisiana, by C. F. Watts.
Financial history of Illinois, by Prof. N. A. Weston.
Financial history of Indiana, by Prof. W. A. Rawles.
Financial history of New Jersey, by E. M. Dawson.
Financial history of Connecticut, by Prof. F. R. Fairchild.
License taxes in the Southern States, by Prof. H. A. Willis.
History of clergy taxes and quit rents in Maryland, by Prof. B. W. Bond.
Comparative study of the financial development of certain of the larger cities of the United States, by O. C. Lockhart.

Professor Gardner is also employing Miss Lorian P. Jefferson, a recent graduate of the University of Wisconsin, to make search for material in the principal libraries of the country relative to his special work.

The number of persons employed in this division is 26.

Division 12.—The Negro in Slavery and Freedom.

Mr. Alfred H. Stone, in charge of this new division, reports good progress. Since his first report Dr. W. E. B. Dubois has completed and published his study, "Economic cooperation among Negro-Americans"; Mr. R. R. Wright, jr., "The Philadelphia colored directory; a handbook of the religious, social, political, professional, business, and other activities of the negroes of Philadelphia, 1908."

The following articles have been contributed during 1907–08:

Home ownership and savings among negroes of Philadelphia.
Negro rural communities of Indiana and Ohio.
Negro communities of New Jersey.
Negro governments in the North.
Recent improvements in housing among negroes in northern cities.
Negroes in business in the North.
The rise of the negro professional class in the North.
Negroes in skilled trades in the North.
The industrial handicap of the northern negro.

Mr. Stone himself has published Some Problems of Southern Economic History, The American Historical Review, July, 1908.

Prof. E. P. Puckett has completed a study on the free negro in Louisiana, and Dr. R. R. Wright, jr., a study of the free negro in Maryland. Both of these works will be published this fall or winter.

Dr. G. T. Surface has nearly completed a report on the economic condition of certain groups of negro miners.

Dr. W. L. Fleming has collected a great mass of material on the transition from slave to free labor, publishing a few articles based on his researches. This material will be put into final shape this winter.

Mr. Wilson has completed and handed in the final report on slave-holding among negroes, and Professor Thomas has submitted a final report on the free negroes in Florida.

Mr. R. R. Wright, jr., has completed a very extensive study, perhaps the most extensive ever made, on the economic condition of the negro in the Northern, Eastern, and Western states. This report has been submitted in part and is now getting into final shape. He has published several papers in connection with his work.

Dr. T. J. Jones, of Hampton Institute, has in progress a study of the influence of industrial schools on the economic condition of negroes. This work is being done in cooperation with Tuskegee, Hampton, and other institutions.

Mr. Stone has definitely outlined the final portion of his work and has begun the actual writing of it.

Fourteen persons are employed in this division.

INDEX OF STATE DOCUMENTS.

This work is under the supervision of a committee on bibliography, consisting of Profs. Henry B. Gardner and Walter F. Willcox, and Dr. Davis R. Dewey, and the work is being done directly by Miss Adelaide R. Hasse, of the New York Public Library. The main work of compilation has been completed and Miss Hasse is devoting herself to filling in the gaps. The volumes for Maine, New Hampshire, Vermont, Rhode Island, New York, and Massachusetts have been completed and published, and additional volumes are appearing as rapidly as they can be handled.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

Certain portions of that unending stream of reproductive matter which has come down to us from the time when life began on earth and by changes in which all evolution has taken place are now under our careful observation and to a large extent under our control. It is the business of the Department of Experimental Evolution to study the behavior of this germ-plasm and to note its reaction to the conditions we impose.

At present our index of the qualities of any germ-plasm is the collection of characteristics shown by the individuals (somas) that arise from it. Each soma is the biological analysis of its germ-plasm. The breeder as he examines his produce selects blood lines or strains on the basis of that produce. And in nature, by the acceptance or rejection of particular individuals, any peculiarities that arise in the germ-plasm are preserved or destroyed.

As just stated, evolution consists of changes in the germ-plasm. These changes are chemically appreciable, for, as Reichert and Brown† have shown, the hæmoglobins of different genera of mammals crystallize in a characteristic manner, and T. B. Osborne has demonstrated‡ that the proteins of various grains are chemically unlike. These changes are biologically appreciable in the variations of the somas that result. Formerly it was held that the germ-plasm is undergoing a slow change and by a selection of streams varying in the right manner we might, in the course of time, build up a new and favorable characteristic. To-day a hopeful hypothesis is that changes occur in the germ-plasm suddenly and in large amount, so that each results in a new characteristic.

While the soma is for us the analysis of the germ-plasm we are studying, we have to recognize that this analysis is subject to certain errors. Of these one of the most difficult to eliminate is the error of variation of the soma under different environmental conditions. This is the "ontogenetic variation" of certain authors and the "fluctuation" of others. Current hypothesis is that fluctuations are not indicative of the constitution of the germ-plasm, but only of the external conditions in which the soma has developed; but this hypothesis is too simple, for external conditions do not produce always the

* Address: Cold Spring Harbor, Long Island, New York. Grant No. 478. $28,200 for investigations and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, and 6.)

† E. T. Reichert and A. P. Brown: The crystallography of hemoglobins. Proc. Soc. Exper. Biol. and Med., v, pp. 66–68.

‡ Amer. Jour. of Physiology, 1906–07.

same result on all developing somas, but, on the contrary, the result varies with the responsiveness of the soma and this is a function of the germ-plasm. A large series of investigations into the laws of fluctuations and the relations of fluctuations to varying nutrition are being carried out by Dr. J. Arthur Harris at this Station.

Another error in the soma as an index of the characters of the germ-plasm is possible whenever the germ-plasm contains the potentiality for a low degree, or the absence, of a quality as well as for a high degree. A particular soma will frequently show only the higher degree—the lower degree is veiled by the higher. This error may be corrected by the study of a large number of somas from the given germ-plasm, since some of these will lack the higher quality and reveal the lower. Thus, pigmented flowers or hair may veil a potential albinism in the germ-plasm, but a certain proportion of the offspring will, under proper breeding, be albinos. Again, it frequently happens that two or more factors are required to produce a visible result. If one factor alone is present in the germ-plasm it will not be revealed in the soma. The germ-plasm first reveals this factor by its behavior when the missing factor is added by crossing. Thus, the germ-plasm of the yellow canary has a pattern but no pigment to reveal it in the soma. When to this germ-plasm is added the pigment-forming quality of the "green" canary, or of some other species of finch, the pattern is revealed in the soma of the hybrid. From a consideration of the foregoing facts it is plain that a single soma does not afford a complete analysis of its germ-plasm; but by using special methods many somas may, together, be made to reveal the complete content of the germ-plasm.

Using, with proper care, the soma as the analysis of its germ-plasm, we seek to study the origin of changes in germ-plasm. First, we have paid attention to cases where, it is alleged, the germ-plasm is undergoing a sort of natural, one might say spontaneous, change. The most famous case of this is that of the evening-primrose, to which de Vries called attention. We are breeding evening-primroses extensively, and some of the results of our work have been published in conjunction with studies made by Dr. MacDougal.* The capacity of this wonderful plant for inciting investigations upon itself seems unlimited. We have only begun an era of investigation into its germ-plasm; and in this plant the structure of the germ-plasm of different species exhibits peculiarities that can readily be seen with the microscope. Miss Anne M. Lutz has devoted much time to the study of the stainable bodies (chromosomes) of the various species and has found the number to vary greatly, as, *e. g.*, 14, 15, 28, 29, 30. When a species with 15 chromosomes is crossed by one having 30 the hybrid offspring have 22, being half-way between the parental numbers, but a few show the ancestral group numbers

* Carnegie Institution of Washington, Publications Nos. 24 (1906) and 81 (1907).

of 15 and 30 again. The structures in the germ-plasm are thus inherited exactly like the somatic characters; and this is the first time that such parallelism has been traced.

What induces mutations in the germ-plasm is not exactly known, yet it can not be doubted that they frequently result from the direct action of certain environmental agents. Years ago Bonnier transplanted alpine plants to the lowland and *vice versa* and got certain modifications of their germ-plasm as a result, so that their descendants, when reared in their former ancestral homes, for a generation or two at least, were quite dissimilar from their cousins that had not been transplanted. Tower (Carnegie Institution of Washington publication 48) states that he found a similar effect on the color of transplanted potato-beetles. Dr. F. E. Lutz finds reason for concluding that climatic conditions similarly have determined the shortening of the wings of the northern crickets. The view is strengthened by the results of experiments which seek to modify the germ-plasm directly. Some years ago our correspondents, M. Standfuss and E. Fischer, of Zurich, were able, by abnormal temperature, to alter permanently the germ-plasm of certain moths. Tower has done the same with beetles, MacDougal with plants by chemical means, and R. H. Johnson has gained results still unpublished that are probably similar to those of Tower. Some efforts were made during the year with the assistance of Prof. C. C. Guthrie, of St. Louis, to influence the germ-plasm of poultry directly by chemical means, but without result. It is proposed to extend at this Station next year the work of inducing mutations.

The modification of the germ-plasm by the action upon it of the soma is still believed in by most people, as well as a respectable body of biologists. Recently Prof. C. C. Guthrie (Jour. Exper. Zoology) of the Medical School of Washington University engrafted ovaries from a black hen upon a white one and *vice versa*. He is confident that the transplanted ovaries were functional and produced eggs which, however, showed in the embryo that developed from them some influence of the foster-mother. His work, involving a somewhat difficult technique, is important, although I disagree with Guthrie's interpretation. Upon my invitation, Dr. Guthrie spent some time at the Station during the winter. Experiments somewhat in this line were started here and future lines of work considered. At present no satisfactory proof that the germ-plasm derives specific characteristics from the soma is forthcoming.

In contrast with the foregoing still difficult and uncertain method of influencing the germ-plasm is a method of very great certainty, yielding results of such interest that the great bulk of our studies so far have been made with it. I have spoken of the stream of germ-plasm; in reality it is a very complicated affair, composed of many tributary, parallel streams, cross-cuts, and anastomoses. They resemble rather the inextricable network of bayous, characteristic of deltas or other flat, irrigated countries. For in all sexually repro-

ducing organisms there is a constant interchange of materials from one stream to another. As one sometimes sees a muddy red stream emptying into a clear river and can trace the color for miles, so in the mingling of germ-plasms in sexual reproduction a single character may be traced through generations. In most organisms the mingling of germ-plasms is immediately followed by the development of a new soma; and this is fortunate for the biologist, since there is the least delay between making his mixture and learning the result of the mixture as revealed by the somas. In the new soma the germ-plasm remains for a time in an immature condition, incapable of further mixing. The usual period required for ripening is a year—and this fact limits the speed of our progress. But in certain species generations succeed each other with great rapidity; thus the vinegar-fly takes only 10 days between generations. This material has proved very valuable in the hands of Dr. Lutz, who has reared over 40 generations in the last 2 years.

From the study of mingled germ-plasms it appears that the same laws hold whether the components be very unlike or differ in only a single character; for we have studied the effect of crossing distinct species and varieties, and the behavior of individual differences in ordinary matings. The study of hybridization is of prime importance for evolution, for it appears to be a common rule that a character that has arisen in one species of a genus is by hybridization engrafted on to some of the individuals of various other species, thus multiplying the number of species. This has been worked out by Dr. Shull, of this Station, for the common shepherd's purse, *Bursa*. The same thing is being worked out by Dr. Ezra Brainerd, of Middlebury, Vermont, in the violets. And the lady-bird bettles (coccinellids) that Mr. Roswell Hill Johnson has been working with since his connection with this Station prove the same thing to be true for a large group of insects. These results could hardly have been achieved, however, without a thorough knowledge of the laws of inheritance of characteristics, and this Station has sought since its inception to contribute to the determination of these laws. To this end experiments have been made on crossing poultry, canaries, cats, sheep, and goats, insects of several species, and many species of plants, and we have had associated with us Dr. Castle, of Harvard University, who is working on mice, rats, guinea-pigs, and rabbits. The general outcome of this work is the accumulation of a lot of pedigree data—much of it quantitative—the like of which exists, I venture to think, nowhere else in the world. These data have as yet been only partially worked up,* but in general they confirm the fundamental importance of Mendel's law; they support, in many cases, the theory of factors by the union of which alone visible qualities appear and they have led to a general theory of "dominance" in Mendelian inheritance according to which a quality present in a higher degree dominates over the lower degree or the entire absence of the quality.

* Carnegie Institution of Washington Publications Nos. 23, 24, 49, 52, 70, 81, 95.

In connection with Mrs. Davenport I have begun a series of studies into normal human inheritance. A paper on inheritance of human eye-color was published last autumn (Science, Nov. 1, 1907), in which it was shown that blue-eyed parents can have only blue-eyed children, but that if either parent has brown eyes the children may be also of that type. With these results the work of C. C. Hurst, of England, published this spring, is in full accord. In May we published in the American Naturalist results of our studies on the inheritance of the form of the hair, proving that two straight-haired parents have only straight-haired children, but that if either parent is curly-haired at least some of the children may be of that type also. The results of studies on hair-color—a very complex subject—are nearly ready for publication and show that the amount of black pigment in the children does not ordinarily exceed that of the darker parent. Much additional data is at hand and will be reduced as fast as possible. The practical importance of the proof of the application of the modernized Mendelian law of inheritance to man is that it enables us to predict the marriage matings that may be expected to yield a particular type of offspring. If we have hitherto made little progress in eugenics it is because there has been little precise knowledge as to the result of any mating. When such knowledge has been gained and formulated we may expect educated persons to take advantage of it.

Our generalization that the quality of a character tends to rise in the offspring to no higher a grade than in the parent helps account for the facts of the frequent injurious effects of continued inbreeding. If in both parents any organ stands at a low level it will stand at that level or lower in the children; if relatives, with the diminished grade, be again inbred the organ drops to a still lower grade or may in time disappear altogether. Of the injurious effects of inbreeding Dr. Shull has again brought evidence in the case of corn; there is evidence in poultry; even in the vinegar-flies (*Drosophila*) Dr. Lutz has clear evidence of degeneration of the wings; and in our human records we have cases of albinism, imperfect sense-organs, and low intelligence. In accordance with this generalization qualities tend to run downhill unless lifted by union with a quality of higher grade—here we see the advantage of outcrossing in strengthening the stream of germ-plasm.

DETAILED REPORTS ON SCIENTIFIC WORK.

HEREDITY.

Poultry.—In this work 59 pens were maintained. About 12,000 eggs were incubated and 3,546 chicks hatched. As a matter of some physiological interest may be given the weekly record of egg-laying, in 4-weekly periods, of the 350 to 320 hens that constituted our flock.

For 4-week period beginning—

Sept. 1	546	Jan. 19	863	June 7	650
" 29	309	Feb. 16	2,556	July 5	253
Oct. 27	190	Mar. 15	3,736	Aug. 2	223
Nov. 24	299	Apr. 12	4,261		
Dec. 22	284	May 10	3,082	Total	17,252

Noteworthy are the grand period of maximum egg-laying from the middle of March to the middle of May and the period of depression from July 1 to January 15. The fluctuations in the latter period are due chiefly to feeding, as a diet of meat after prolonged abstinence will quickly double, at almost any time, the egg-yield; but on the withdrawal of such stimulating food the egg-yield rapidly diminishes. Another factor contributing to the irregularity of the egg-yield is the removal for market during June and July of about half the laying hens, and the increase in the number of laying birds during January and February by the maturing of the young stock.

The entire laying plant was removed during December and January a distance of about a mile, to a farm on the plateau, where the conditions are much better for the health of the hens. Artificial incubation and brooding were carried on at the laboratory and its immediate vicinity. In addition to poultry some guinea-fowl were bred.

Finches.—Sixty pairs of breeding canaries were mated and 5 of other finches. A total of 329 birds hatched, but owing, probably, to inadequate heating facilities only about 100 birds were reared. This number includes 3 hybrids between gray and white Java sparrows, which show gray dominant. During the year our stock of canaries was increased by the importation of some of the more novel and at the same time expensive varieties. Owing, perhaps, to incomplete acclimatization these have bred poorly this season.

Sheep and Goats.—Eight sheep and 9 goats were born during the year; in both species white fleece is dominant over black, but not over red. As a pure white Angora goat was used as sire during the present season only white or white-and-red kids were born. The neck "wattles" are dominant over their absence. During the year we received from Dr. A. G. Bell, a black ram with 6 nipples, which will be used in place of our former ram to prevent too close inbreeding. No increase in the number of nipples beyond 6 has yet occurred.

Cats.—The limitations of room have caused this experiment to come to a partial standstill. It is planned to provide improved and enlarged quarters for it. Some 20 cats were born during the year.

Drosophila.—The study by Dr. F. E. Lutz of the inheritance of the abnormal venation of the fruit-fly has been continued through more than 40 generations. The results will be ready for publication shortly. The inheritance of the scalloped wing was also tested and the inheritance of dwarfness. If time permits this latter work will be continued and the effect of environment will be considered. However, special stress will be laid during the coming year upon the work with *Gryllus.*

Gryllus.—The inheritance work with this genus has been continued along the lines laid down four years ago. While Dr. Lutz has been chiefly concerned with the wing dimorphism, data have been secured concerning all of the important organs. About 2,000 pedigreed offspring have been obtained this season. In May Dr. Lutz made a short trip to Cuba and Mexico with

a view to arranging transplantation experiments. About 500 offspring are now being reared from the living material brought back, and some material was also collected for the purpose of studying geographic variation. It is hoped that the living material secured on this trip will breed in the greenhouse here during the winter, when the native crickets are hibernating. Dr. Lutz plans next summer to pay especial attention to the effect of humidity upon the wing dimorphism.

EVOLUTION IN THE COCCINELLIDÆ.

This work, which has been continued by Mr. Roswell Hill Johnson, is now drawing to a close, owing to his impending departure from the Station. Reports on the results attained are being prepared. His major paper deals with determinate evolution in the color-pattern of lady-beetles. He has also written several papers of more general import, the outcome of reflections and observations on these insects.

BREEDING STRAINS OF PLANTS.

Dr. George H. Shull, although occupied during much of the year (from February 15 to May 30) with his study of Mr. Burbank's horticultural methods and results, has been able to continue most of the strains listed in last year's report. He concluded his work on *Bursa pastoris* and has presented an important paper on the subject for publication. This species shows its composite nature in a fashion as to make it hardly less interesting than the evening-primrose. On August 14 he started on a tour of the principal plant-breeding establishments of Europe.

In hybrid beans it has been demonstrated that a mottled seed-coat, which appears as a novelty in several crosses, becomes evident only when in the heterozygous state. Individuals which possess the mottling factor in the homozygous condition are indistinguishable from those which lack this factor altogether. The mottled character which appears as a novelty in these crosses can not be segregated as a permanent characteristic of a pure strain, but plants possessing this character, when self-fertilized, continue to give only 50 per cent of mottled offspring. They form in respect to mottling a mid-race. The peculiar behavior of the mottling in these beans has given rise to the ratio 18 : 18 : 6 : 6 : 16, which has not been reported hitherto. The fact that the pure-bred dominants with respect to mottling are not mottled, even when pigment is present, makes it impossible to determine at this time whether the mottled pattern was derived from the pigmented bean or the white one, though it was assumed at first that it came from the latter. Means are now at hand for the solution of this problem, but the necessity of leaving the cultures on August 14, before the beans had begun to bloom, has made it necessary to postpone this matter until another season. Two other cases of latency have also been demonstrated in these beans. Both the White Flageolet and the

Prolific Black Wax have allelomorphs for a dark yellowish-brown color, which can be demonstrated by appropriate breeding-tests, and Ne Plus Ultra, which is dark orange, carries light yellow as a latent character. The crosses of the latter variety lend support to the "presence and absence" hypothesis. In discussing these results, four different types of latency have been recognized, namely, (*a*) Latency due to separation, as when two allelomorphs which are jointly necessary to the production of a visible character do not occur together in the same soma. This condition is very frequent in the case of albinos. (*b*) Latency due to combination, in which the cooperation of two allelomorphs in some way destroys or prevents their characteristic manifestations, thus rendering the individual possessing both of the allelomorphs in question quite indistinguishable from individuals which possess neither of them. (*c*) Latency due to hypostasis, the very common case of complete invisibility of one characteristic in the presence of another, the latter characteristic not being perceptibly modified by the presence of the former. (*d*) Latency due to fluctuation, when characters which are normally present are temporarily suppressed through malnutrition or other similar causes. The first three of these types of latency is exemplified by the hybrid beans, and each results in the production of definite ratios which differ from the typical Mendelian ratios without in the least affecting the fundamental principle of segregation of "pure" gametes and their union according to the laws of chance.

Studies on the effects of cross- and self-fertilization in maize have given further evidence that an ordinary field of Indian corn consists of a series of more or less complex hybrids among numerous elementary species or biotypes, and that the apparently injurious effects of self-fertilization are due simply to the unfavorable comparison of pure strains with their hybrids, and of less complex hybrids with more complex ones. Self-fertilization sooner or later reduces any pedigree to the condition of a pure strain by eliminating its hybrid elements. According to this hypothesis, when the strain is once reduced to a pure state, no further deterioration should result from continued self-fertilization. All the evidences available at this time appear to support this proposition.

In the common large-flowered garden sunflower, or Russian sunflower, there are two elementary forms, one of which is practically unbranched, the other having several to many lateral branches, particularly on the upper portion of the central axis. When the unbranched type possesses a few branches, as it does occasionally, these are near the base of the central axis. In crosses between these two forms, the branched type is dominant over the unbranched, the heterozygotes being quite indistinguishable from their branched parent. Segregation is perfect, regardless of the fact that the branching habit is rather easily modified by environment. In crosses between the Russian sunflower and the semi-wild *Helianthus annuus* of the prairies, the behavior with respect to branching is quite anomalous, and it is expected that this may throw some light upon the phylogenetic relations of these two forms.

In *Lychnis alba* purple and white flowered individuals give typical Mendelian crosses, and several abnormalities or atypic conditions are found to be rather strongly though imperfectly inherited. A large number of crosses have been made this year in *Lychnis,* particularly for the purpose of attacking certain problems relative to the inheritance of sex.

In crosses between yellow and pale flowered forms of *Verbascum blattaria,* the yellow is dominant. In nearly every F_2 family the number of pale-flowered individuals has been in excess of expectation, and considerably so in one or two families. Further crosses have been made to determine whether this is merely a matter of random sampling or whether it is a normal condition, and if the latter, what may be its cause.

Many pedigreed families of the Shirley poppy have been studied, and the general hereditary relations of the various tints and color-patterns are more or less clearly discerned. While the range of color is great, the variation within this range is not continuous. There are relatively few color-types, and within each of these there is but slight variation. There are also some obvious irregularities involving latency and perhaps also coupling.

The scope and extent of Dr. Shull's pedigree work during the past season is concisely shown in the following table, arranged as in his previous reports:

Species.	No. of pedigreed families.	No. of individuals.	Species.	No. of pedigreed families.	No. of individuals.
Chrysanthemum leucanthemum	1	6	Oenothera lata	4	181
Digitalis sp.	2	261	Oenothera nanella	1	75
Gaillardia sp.	2	231	Oenothera rubrinervis	3	150
Helianthus annuus	39	1,988	Papaver rhœas	83	2,060
Lychnis alba	19	1,374	Pentstemon sp.	1	1
Lycopersicon lycopersicon	2	40	Phaseolus vulgaris	546	10,000(?)
Lycopersicon sosonopsis	3	60	Trifolium hybridum	4	200
Oenothera cruciata	4	82	Verbascum blattaria	12	1,200
Oenothera gigas	2	65	Verbena stricta	1	50
Oenothera lamarckiana	11	479	Viola arvensis	2	40
			Zea mays	38	6,500(?)
				780	25,043

Dr. J. Arthur Harris has had general oversight of the preceding cultures during Dr. Shull's absence, and he is in addition making a detailed study of variation, correlation, and heredity of quantitative characters in several varieties of beans. Some 20,000 individually labeled seeds were planted in selected habitats at the Station for Experimental Evolution, in southeastern Ohio, in western Kansas, and at the Missouri Botanical Garden. Also, smaller plantings were made of a number of species to determine their fitness for serious experimental work.

VARIATION AND CORRELATION IN FERAL PLANTS.

Dr. Harris has been making comparative biometric studies on species of *Cercis, Staphylea, Sanguinaria, Hibiscus, Agave,* and *Cassia.* Extensive collections are being made from several habitats and seasons, in order to test the influence of environmental and seasonal differences on variation and correlation constants, and it is hoped that some of the results will be ready for publication shortly. During the year about 200 tables of data and calculated constants have been prepared. Probably these habitat investigations will form the basis of transplantation investigations to be undertaken later.

CELL STUDIES IN HEREDITY.

These were continued by Miss Lutz, who reports as follows: The work upon the chromosomes of the somatic cells of the oenotheras in 1907, reported upon in Year Book No. 6, has been continued throughout the present year on a much more extensive scale.

The investigations of the preceding year having revealed the number of somatic chromosomes for *Oenothera gigas* to be approximately double that of any other form so far studied, the opportunity was at once suggested of securing valuable data upon the question of the behavior of chromosomes in inheritance by crossing *gigas* with a form having the smaller number. Only 3 offspring of *O. lata* female × *O. gigas* male were available for study the first summer, but these showed such remarkable combinations of chromosomal and vegetative characters that it was decided to repeat the cross upon a larger scale the following season. Accordingly seeds were sown and 77 seedlings obtained, all of which were transplanted to the experimental gardens in May. Representative types were photographed in early rosette and late rosette and flowering stages—107 exposures in all—about one-fourth of which were of plants connected with work upon other problems.

Fixations were made of root-tips of 50 of the 77 hybrids in the early rosette stages, and 35 of these have been carefully studied and chromosomes counted. In connection with the microscopical investigations, the vegetative characters of the hybrids were closely observed daily from time of germation to close of flowering season, and continuously observed from 5 a. m. until 7^{h} 30^{m} p. m. daily from July 1 to September 1. The results of these investigations will be published shortly.

Owing to the scarcity of pollen produced by these hybrids, seeds were obtained only after the most persistent efforts at artificial self-pollination for six weeks following the opening of the first flower. Although the seeds have not been harvested, it is believed that by this means guarded self-pollinations were secured of the representative types of hybrids, and in a number of cases reciprocal crosses with *gigas.* These second-generation offspring will form the chief subject of study for 1909.

In addition to the above, 50 individuals of pure-bred *gigas* grown directly from de Vries seed have been described, types photographed, and root-tip fixations made for the study of chromosome variation. All forms (41) found among the following of Dr. Shull's cultures differing from the parental type were similarly treated.

Oenothera lamarckiana.	Oenothera rubrinervis.
gigas.	cruciata.
nanella.	lata ♀ × O. lamarckiana ♂.

CONSTRUCTION.

A shed of brick and concrete connecting with the stable and having an outside length of 50 meters was completed. This gives much-needed space for cows, for storing wagons, brooders, pipe, and other bulky material, and also a room for agricultural implements. A concrete pit for manure was also constructed.

The poultry plant was moved to a situation on the hill. Some two months were employed in this work and clearing the land and setting up the necessary fences. A small portable house was purchased and set in the midst of the plant for the temporary use of the poultryman. It is proposed to use this, henceforth, for experimental work.

A 5-inch well was driven at a desirable point on the land of the Biological Laboratory by permission of the Brooklyn Institute, in consideration of supplying its laboratory with part of the water during two months of the year. A flow of 90 gallons per minute was obtained at a depth of 76 feet, at a cost of $305. This supplies a ram which pumps water over the entire plant, the pipe line being about 1,300 feet. Thus at a total cost for well, pipe, and ram of $500, about $75 per year for electric power is saved and better service given. The cost of repairs of the electric pump had become burdensome, and it is believed with the ram a further saving will be made in repairs.

Three weeks of the time of the constructor was spent in replacing the decaying basement floor of the residence with concrete. The construction of a shelter for the launch has been begun.

EQUIPMENT.

Among the larger items of equipment were additional cabinets for storing microscopical slides and for insects, breeding-cages for canary birds, and shelves for the library.

MAINTENANCE.

The greenhouse, poultry houses and some outside woodwork of the main building were painted. One of the cesspools was connected with an underground sewerage-disposal system of the Waring type. To take care of the occasional violent rains that were eroding the soil of our garden and destroying the roads, a system of catch-basins and distributing-pipes was laid, so that now this water is largely carried to the sea underground.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

After a scientific undertaking is organized, properly equipped, and fairly started upon its way, its best report of progress is its published work. The Geophysical Laboratory has entered upon a systematic study of rock formation. This means the study of the relation of the component minerals which go to make up the typical rocks. It may be directed toward the great igneous rock-masses which are first in structural importance, toward the metamorphic rocks in which much earth history is recorded, or toward the ore deposits which are first in economic interest. The choice at the beginning has no especial significance. Researches must eventually be undertaken in all these directions. The most important questions at the beginning are: (1) practicability, to start with simple and accessible relations—the behavior of a single mineral or simple mixture of two—and to proceed from these to more complicated cases with the advantage of more competent experience; (2) quantitative methods, to use pure minerals which are not rendered abnormal through by-mixtures of unknown behavior, and to measure the forces (pressure, temperature) to which they are subjected.

It must be an organized effort, for chemistry must guarantee the initial purity of the component minerals, and physics must provide and measure the temperatures and pressures, physical chemistry must correlate the reactions, and petrology must fit the product into its proper niche in the earth's rock-system. This, in a word, is the Geophysical Laboratory organization. A substantial building has been provided for it, which was described in the Director's report of a year ago, and the work of this year has served to bring the plant up to its full efficiency.

Two branches of the work are not represented in the published papers of this year and may receive brief mention here:

Lime-Alumina-Silica Mixtures.†—All of the mixtures between pure silica and pure alumina have been fused and examined microscopically. The application of our usual methods discovers only one compound between these two oxides—Al_2SiO_5, or sillimanite. The pure mineral prepared in the laboratory presents several interesting details of structure and has an index of refraction slightly lower than the natural mineral. Its melting-point falls a little higher than that of platinum. Some work published by the Königliche Por-

* Address: Upton Street, Washington, D. C. Grant No. 476. $40,000 for geophysical research. (For previous reports on geophysical work see Year Books Nos. 3, 4, 5, and 6.)

† E. S. Shepherd and G. A. Rankin.

zellan Manufactur suggested the existence of a second compound in this series, but their preparations were heated in the presence of carbon and the temperature measurements made with Seger cones, so that the results are not quite convincing. Although the region in which this supposed compound occurred has been examined with the greatest care, neither a maximum nor any new solid phase has been discovered. Between the composition of sillimanite and pure alumina the solid phases are sillimanite and alumina, the latter containing a small admixture of silica in solid solution, indicated by its slightly altered properties. The sillimanite-alumina eutectic falls at about 67 per cent alumina. Between sillimanite and silica the solid phases are tridymite and sillimanite, with a eutectic which is somewhat difficult to locate. With increasing quantities of silica, the viscosity of the melt makes such observations very difficult, and all members of the series melt at temperatures too high for determination with the thermocouple.

The attempt to prepare the two modifications—andalusite and cyanite—which occur in nature with the same composition as sillimanite, has not been successful. After overcoming considerable experimental difficulties, we succeeded in obtaining a small quantity of sillimanite glass, but the recrystallization of this glass, either at low temperatures, dry, or with 10 per cent sodium chloride in bombs, resulted invariably in the formation of sillimanite. Attempts to produce either of the modifications by metathetical reactions have thus far yielded no positive results, though traces of crystals similar to andalusite appeared in a few of the preparations. We have been able to show that the change from either of these modifications to sillimanite is not reversible. When heated to temperatures above 1,200° both go over slowly into sillimanite, the change for small charges of finely powdered material requiring about 24 hours (at 1,200°). In bombs at temperatures between 400° and 500° the two minerals are not appreciably affected. It is worth noting that while andalusite when heated readily changes into a substance resembling sillimanite, the cyanite appears rather to decompose without yielding any readily identifiable product. At higher temperatures, approaching the fusion-point of sillimanite, both give very fair sillimanite.

In the lime-alumina series, both microscopical and thermal examinations have been made of all the compositions with fair success. The existence of three definite maxima with corresponding eutectics has been established—$CaO.Al_2O_3$, $3.Al_2O_3.5CaO$, and $Al_2O_3.3CaO$. The first and last of these compounds melt above 1,600° and have therefore to be determined with the optical pyrometer. The intermediate compound at 52 per cent is well within the range of the thermocouple. The 1 : 1 compound is a very definite, well-crystallized, birefracting compound which has been shown to be without other modifications. The 3 : 5 compound exists in two forms. In its stable condition it is isotropic, but it also appears in the birefracting form in monotropic relation to the first. The compound $Al_2O_3.3CaO$, occurring at about 37.78 per

cent alumina, is perhaps the most important one of the series in that it may appear later in the investigation of the Portland-cement portion of the diagram. This compound seems to be partly dissociated at its melting-point, so that whatever precautions are taken it never appears absolutely pure. There is always a slight excess of crystallized lime and a corresponding amount of the 52 per cent compound. Prolonged heating at 1,300° causes these excess components to disappear. It is well crystallized and isotropic. All the mixtures of the series up to about 60 per cent are readily attacked by water and easily dissolved in moderately dilute hydrochloric acid.

The completion of these two axes of the triangular diagram prepares the way for the investigation of ternary mixtures of these oxides which is now under way. Guarinite and meionite have been prepared synthetically in the course of the investigation.

Extreme Pressures.—The application of pressures of a magnitude comparable with that which may have obtained in the interior of the earth was necessarily postponed so long as the laboratory remained installed in the Geological survey building on account of the obvious danger of accident attending such experiments. Since the removal to the new laboratory building, attention has again been directed to this question and the development of the necessary plant and methods of measurement placed in the hands of Dr. A. Ludwig, of Dusemond, Germany, who has had unusual experience in this field. A plant is being installed and is now nearly ready for test which is expected to develop measured pressures up to 3,000 atmospheres or more in various gases, in which it is first proposed to repeat the experiments upon the liquefaction of carbon with which Dr. Ludwig's name is already connected; and afterward, to attempt to measure the effect of such pressures upon rock formation, both in the presence of water and without it. Bombs in which compressed water-vapor is made to react on minerals for moderate ranges of temperature have been in successful use for some time.*

Published Work.—A review of the published work of the year follows. In establishing ourselves in the new laboratory building, considerable attention has been given to the perfection of methods and apparatus, and a number of the papers which follow (Nos. 1, 2, 3, 5, and 7) will be found to deal with this phase of the investigation. Nos. 6, 8, and 9 describe apparatus suggested by these studies which finds application outside of the work of this Laboratory.

(1) What is the most important portion of a thermoelement?† (Abstract.) Walter P. White. Phys. Rev. 26, p. 535, 1908.

Along a thermoelement as ordinarily used, there are three temperature regions; one, fairly constant, at each end, and an intermediate gradient region

* Annual Report for 1907.

† Abstract of a paper presented at the Washington meeting of the Physical Society, April 24–25, 1908.

where the temperature changes from one of the end values to the other. (In an element used with a cold junction in ice, there are usually two such temperature systems in series.) The present paper applies only where this temperature distribution exists. In such cases, applying the formula for electromotive force of a thermoelement which is not perfectly homogeneous,

$$E = \int \theta dH$$

(θ temperature, H thermoelectric power, E electromotive force), it is easy to show that, except for second-order corrections: (1) the temperature measured is that of the junction; (2) but it is measured in terms of the thermoelectric power of that part of the thermoelement which passes through the gradient region of temperature, and not of that lying near the junction; (3) inhomogeneities, permanent or temporary, in the other portions are much less important than in the gradient region.

This conclusion is little more than an extension of the well-known rule that solder or other foreign material at the junction affects the electromotive force but little. Nevertheless, it seems worth stating, both on account of its importance and because much in the literature seems to point to a very different conclusion and to emphasize the importance of the (usually) really unimportant portion of the thermoelement near the junction.

The following practical conclusions follow:

(1) In selecting wire for a thermoelement, the gradient portion is the only part where great care needs to be exercised. The production of a good thermoelement is thus easier than has sometimes appeared.

(2) If an inhomogeneous element is shifted to a different depth in the bath or furnace, it (in general) at once becomes a different element. The effect of a change in the material near the junction, however, is much less important.

(3) In cutting off a contaminated platinum thermoelement to restore its original value, it is usually sufficient in practice to cut off only so much that fresh uncontaminated wire occupies the gradient region.

Commercial constantan wire has been obtained whose original variations in thermoelectric power were 0.001 of the electromotive force against copper. By suitable selection and combination of this wire, thermopiles were easily constructed good to 1 part in 100,000, that is, 0.001 degree at 100°. These even showed no variation in reading equal to 0.001 degree when the depth of immersion in a constant temperature bath at 100°, and therefore the position of the gradient region, was varied several centimeters.

(2) Specific heats at high temperatures.* (Abstract.) Walter P. White. Phys. Rev. 26, p. 536, 1908.

The substances under examination were dropped from an electric resistance furnace into the calorimeter described a year ago. The errors of the calorimeter were negligible. The loss of heat in the air was eliminated by first determining the heat given out by an empty platinum crucible at various temperatures and then subtracting this as an empirical correction from the total heat of crucible and included material. The empty crucible was weighted with platinum so as to keep constant conditions with regard to the splash, etc.

* Abstract of a paper presented at the Washington meeting of the Physical Society, April 24–25, 1908.

The total loss of heat of the crucible alone (and this includes also the slight loss from the formation of steam as the crucible strikes the water) was only 4 per cent. The crucible was dropped electrically (Harker's method) by melting a supporting wire. This was done automatically by the swinging aside of a shield between furnace and calorimeter. The principal source of error (1 per cent or more) was found in the uncertain temperature distribution within the furnace; a longer and narrower furnace is expected to diminish this. The accidental errors averaged about 0.3 per cent, that is, duplicate results usually agreed as well as this.

(3) Die Justierung des Abbe-Pulfrischen Kristallrefraktometers. Fred. Eugene Wright. Zeitschr. f. Instr. 28, p. 201, 1908.

A detailed statement of the adjustments which are necessary to establish the magnitude of the errors occurring in the use of the Abbe-Pulfrich crystal refractometer. In this paper serious exception is taken to the practice very generally indulged in by instrument makers of concealing adjustment screws with the intention of preventing any adjustment of the instrument after it leaves the factory. Where apparatus is intended for rough or rapid work, or for classroom demonstrations, where high accuracy is not sought, such a practice is more or less justifiable and tends to prevent the apparatus from being tampered with by inexperienced students; but it becomes a serious limitation in the use of a measuring instrument for research work if its errors can not be promptly and accurately determined or if it can not be quickly and conveniently readjusted when necessary.

(4) The rôle of water in tremolite and certain other minerals. E. T. Allen and J. K. Clement. Amer. Jour. Sci. (4), 26, p. 101, 1908.

A study of five different specimens of natural tremolite, two of them of exceptional purity, proves that all contain water ranging from 1.7 to 2.5 per cent. This water is lost gradually with rising temperatures without any loss of homogeneity and with very slight change in the optical properties. The water is therefore not chemically combined, although the mineral in the powdered state is not completely dehydrated under 900°. It is to be regarded as dissolved water, and tremolite as a solid solution. A diopside from a metamorphosed limestone contained 1 per cent of water and behaved in practically the same way, though presumably the diopside of eruptive rocks is anhydrous.

The amphibole kupfferite and a specimen of beryl contained respectively 3.8 per cent and 2.5 per cent of water, which they lost very slowly at comparatively high temperatures (400° to 800°) and still retained their homogeneity. With them, however, the loss of water appeared to progress so slowly at these temperatures that the total water could not be driven off in any reasonable time. The beryl lost at the same rate for a long period, both in dry air and in an atmosphere containing water vapor at the partial pressure of about 23 mm., even though this rate appeared to show that the mineral possessed a vapor-pressure of only about 0.5 mm. of mercury. The kupfferite showed a similar behavior, but the fact that it suffered a secondary change in composition at the higher temperatures (probably due to the absorption of oxygen) made this measurement less satisfactory.

All these minerals show important points of resemblance with the zeolites, with which they may broadly be classed, but in one important particular they

differ—at least, this is true of kupfferite and beryl—they do not give true equilibrium with water-vapor at low pressures, while the zeolites under similar conditions do so (Friedel). Diopside and tremolite seem to give off their water continuously, but not indefinitely, with rising temperatures, though it is quite possible the curves represent cases of "false equilibria."

Recent analyses indicate that all the amphiboles contain water. Actinolite, glaucophane, and pargasite contain 1.3 to 3 per cent, mostly retained above 100°. The hornblendes also contain water, though usually in smaller quantity. These facts, taken in connection with the above work on tremolite and kupfferite, lead to the suspicion that the amphiboles generally contain dissolved water as a characteristic constituent, and are solid solutions.

(5) On the measurement of extinction angles in thin sections. Fred. Eugene Wright. Amer. Jour. Sci. (4), 26, p. 349, 1908.

The measurement of extinction angles of minerals in the thin section is one of the most common methods of petrographic microscope practice, and at the same time one of the least satisfactory when accurate results are desired. It is an exceedingly easy matter to measure, with one trial only and on favorable sections, extinction angles with a probable error of ± 1° to 2°, but to do so within ± 10′ is a very different matter. The methods in use for this purpose may be grouped into two classes—those of general application and those of limited applicability. The first class may again be subdivided into two subclasses, either (1) the crystal is revolved between crossed nicols about its position of total extinction, or (2) the crystal remains stationary, and the accuracy of its position for total extinction tested by revolving the upper nicol or by inserting one of several different optical devices to increase the sensitiveness of the test under prescribed conditions of illumination. These devices include the Calderon ocular, the Bertrand ocular, the Bravais-Stöber plate, the Traube plate, also twinned plates and wedges of selenite, artificially twinned plates and wedges of quartz, the circularly polarizing bi-quartz wedge-plate and the bi-nicol ocular. Of these devices the last two are the most universal and can be so used under any given conditions of illumination that the phenomena observed are the most sensitive which it is possible to attain by devices of this type.

On comparing the relative sensitiveness of the different methods under the same conditions, it is found that the method of testing the position of total extinction for the crystal by revolution of the upper nicol is, on colorless mineral-plates, at least twice as sensitive as that of simply turning the crystal to its position of apparent maximum darkness under crossed nicols. Under the same conditions the methods requiring the use of one of the several plates or wedges mentioned above are at least four times as sensitive as the ordinary method. With the exception of the last two devices, however, these different plates do not furnish equally sensitive results for the different conditions of illumination which may arise. In accurate work adjustable sensibility is of prime importance, particularly if a given device is to be of general application. These requirements are best filled by the bi-quartz wedge-plate, by means of which the angle of rotation can be varied from 0° to any desired angle. The two halves of this wedge rotate in opposite directions, and on insertion that angle of rotation can be secured for which the contrast in the intensity of the halves of the field is most striking for a slight deviation of the crystal from its true position of extinction.

An application of the bi-quartz wedge-plate, together with an artificially twinned quartz-plate or wedge, to the accurate adjustment of the petrographic microscope is considered in outline in the second part of the paper, and a method of procedure for accomplishing the same indicated.

In part 3 a simple device for holding and rotating small crystals for the purpose of determining extinction angles, or for measuring optic angles directly, is described briefly, such an apparatus having been found peculiarly useful in work with artificial crystals.

(6) The bi-quartz wedge-plate applied to polarimeters and saccharimeters. Fred. Eugene Wright. Amer. Jour. Sci. (4), 26, p. 391, 1908.

The bi-quartz wedge-plate is suggested as a simple and effective basis for the construction of a polarimeter of adjustable sensibility in which the error from the asymmetry of the Lippich system, together with all the serious complications of mechanism, are completely avoided without loss of accuracy. Such a plate has been constructed and successfully applied to the exact location of crystal extinctions, but unfortunately pressure of other duties prevented the actual construction of a new saccharimeter. Through the courtesy of Dr. Frederic Bates, of the U. S. Bureau of Standards, however, an opportunity was given to test the wedge on a large and accurate standard polarimeter illuminated by homogeneous green light from a mercury quartz-glass arc. Its performance was entirely satisfactory, minute displacements of the analyzer from its position of total extinction being readily observed.

(7) Some new measurements with the gas thermometer. Arthur L. Day and J. K. Clement. Amer. Jour. Sci. (4), 26, p. 405, 1908.

The gas-thermometer problem at the present stage of its development has become primarily a problem for experimental study with two definite purposes—one to increase the accuracy of the measurements, the other to increase their range. The general relations involved are no longer subject to serious question. The progress of recent years has given us electric heating in place of gas and the consequent possibility of regulating the temperature with great certainty and exactness. It has also given us the metal bulb, with a definite and measurable expansion coefficient which is capable of holding the expanding gas without loss. It has discovered a gas which does not diffuse through the bulb or react with it chemically, which does not dissociate within the limits of practicable measurement, and of which the expansion can be expressed with a reasonable certainty in terms of the Kelvin thermodynamic scale. This was the situation in 1900, at the time of the publication of the now generally accepted high-temperature scale covering the region from 250° to 1,150° C., with a probable accuracy of 5°.

Starting from this point in 1904, Professor Holborn, of the Reichsanstalt, increased the range of this scale to 1,600° C., the probable error of the new portion being about 10°. Simultaneously with this effort, work was begun at the Geophysical Laboratory in Washington, with a view to increasing the accuracy of the scale, first over the existing range (to 1,150°), and later, as much beyond this point as it should prove possible to go. Temperature measurements between 250° and 1,150° have been made and form the subject of the present paper. The particular points to which we have given the most attention are the following: (1) To provide a uniform temperature along the bulb by a suitable arrangement of the heating coils. (2) To inclose the fur-

nace in a gas-tight bomb in which the pressure outside the bulb can be maintained equal to that within for all temperatures. This offers three distinct advantages: It provides against the deformation of the bulb through differences of pressure within and without in the region where the bulb material becomes softer. By using the same gas within and without, there is no tendency to diffuse through the bulb-wall from within or without. It enables the initial pressure to be varied within considerable limits, thereby increasing both the scope and sensitiveness of the manometer. The sensitiveness in our instrument with this arrangement was about three times that of the Reichsanstalt. (3) The expansion of the bulb material was determined with great care and is probably accurate within 0.5 per cent. (4) The unheated space between the bulb and manometer has been reduced until the total correction in this hitherto uncertain region amounts to less than 5° at 1,100°. An error of 5 per cent in the determination of its volume or temperature distribution is therefore practically negligible. It is probable that these changes serve to reduce the aggregate error of the gas thermometer in the region of 1,100° to about one-tenth the magnitude which existed at the time of the establishment of the present scale.

Furthermore, and most important of all, these refinements are not limited to this temperature region. It is therefore reasonably probable that the gas scale can be extended to 1,500° or 1,600° with proportionate accuracy. The immediate future of the present investigation will be to undertake this extension.

The interpretation of these measurements in terms of the melting-points of readily available substances encounters certain difficulties. The melting-point of pure salts is not sufficiently sharp and is somewhat difficult of interpretation. The metals which have commonly been used for the purpose are not obtainable commercially in sufficiently uniform purity to guarantee an accuracy of more than 1° at the higher temperatures. This is too large an error for the interpretation of the gas-thermometer scale in its present refinement.

No effort has been made to prepare metals in our own laboratory of exceptional purity, for the reason that such metals would not be available for general use and would therefore be of little service. We have accordingly adopted metals which are carried permanently in stock by dealers from whom the same metal in a nominal quality equal to that which we used can be readily obtained. We have analyzed these with extreme care to show the exact content of the sample supplied to us. We have duplicated the purchases ourselves, and have found no errors greater than 1° in melting-point determinations.

Another difficulty arises from the fact that the melting-points of the purest metals available for use as constants in reproducing a high temperature scale (zinc, silver, gold, and copper) are distributed in such a way that, although they may be *located* upon the gas-thermometer scale with a probable error not greater than 0.5°, the calculation of a similar curve passing through these points does not suffice to *reproduce* the scale with this accuracy. In the region midway between zinc (418.9°) and silver (958.5°) the error of interpolation may amount to 2°, even with metals of exceptional purity. Extrapolation is even more uncertain. This can be avoided by locating intermediate points which are equally trustworthy, if such can be found. We have not been fortunate enough to find points which fulfill these conditions satisfactorily, but hope that we may yet be able to do so.

As the matter now stands, therefore, we have succeeded in perfecting the constant volume gas thermometer until the aggregate error affecting the measurements between 300° and 1,150° appears not to be greater than 0.5°, but we are not yet able to offer adequate assurance that our scale can be reproduced by another with this accuracy. This matter will receive further attention in a later paper.

(8) A telemeter with micrometer screw adjustment. Fred. Eugene Wright. Amer. Jour. Sci. (4), 26, p. 531, 1908.

A description of a convenient instrument for the measurement of distances in geological field work.

(9) A device to aid in the explanation of interference phenomena. Fred. Eugene Wright. Amer. Jour. Sci. (4), 26, p. 536, 1908.

A description of an instructive model for the use of students of optics.

(10) On three contact minerals from Velardeña, Durango, Mexico (gehlenite, spurrite, and hillebrandite). Fred. Eugene Wright. Amer. Jour. Sci. (4), 26, p. 545, 1908.

A chemical and optical study of three contact minerals occurring near the junction of altered limestone and intrusive basic diorite. The specimens examined were gathered by Messrs. J. E. Spurr and G. H. Garrey in Velardeña, Mexico. This appears to be the first recorded appearance of gehlenite on this continent. The others are new minerals which have not been described before.

(11) Thermometric lag in calorimetry. Walter P. White. Phys. Rev., December, 1908.

In recent work in calorimetry by the method of mixtures, several attempts have been made to avoid an error to which considerable importance has been attached, due to the lag of the thermometer. It can be shown, however, that this error does not exist at all: In a calorimetric run by the method of mixtures, all the temperature data lie upon a temperature time curve whose form determines both the cooling correction and the main temperature interval. The *exact instant* at which temperatures on this curve are read is unimportant so long as the temperature *intervals* are preserved. If, now, all temperatures are plotted the same number of seconds wrong, as they would be when the same lagging thermometer is used throughout, no appreciable error can result. The importance of lag in calorimetric thermometers has therefore been greatly overestimated.

The above reasoning points to the existence of another error in calorimetry hitherto generally overlooked, due to the unavoidable lack of uniform temperature during the period of rapid heating, which produces all the effects of a thermometric lag. A correction should be made for this effect.

(12) Diopside and its relation to calcium and magnesium metasilicates. E. T. Allen and Walter P. White. With optical study by Fred. Eugene Wright and E. S. Larsen. Amer. Jour. Sci., January, 1909.

The end members of the system $CaSiO_3$-$MgSiO_3$ both exhibit enantiotropy. The inversion-point in the former is about 1,190°. The α-form, pseudo-wollastonite, is unknown in nature. The β-form is the mineral wol-

lastonite. The β-form of magnesium silicate is the magnesian pyroxene occurring in meteorites to which no mineralogical name has yet been given. At about 1,365° it is transformed into an orthorhombic form quite distinct from enstatite and unknown in nature.

Only one stable compound appears, viz, $CaSiO_3.MgSiO_3$, identical with diopside. It melts at 1,380° and has a specific gravity of 3.275. It was obtained in well-formed, measurable crystals extremely pure, when crystallized from molten calcium chloride.

A eutectic occurs between diopside and pseudo-wollastonite at the composition 60 per cent diopside : 40 per cent calcium silicate. It melts at 1,348°. A second eutectic occurs at 68 per cent $MgSiO_3$: 32 per cent $CaSiO_3$. It is composed of about 95.5 per cent of a mix-crystal containing about 62.5 per cent of diopside: 37.5 per cent magnesium silicate, and 4.5 per cent of α-$MgSiO_3$. Its melting temperature is 1,375°.

Six solid solutions appear in this system. Only two of them contain more than 3 or 4 per cent of the lesser component, and only these will be mentioned here.

(*a.*) β-calcium silicate (wollastonite) forms a saturated solution containing about 17 per cent diopside (8 per cent $MgSiO_3$) : 83 per cent $CaSiO_3$, when crystallization takes place in the neighborhood of 1,050°, *i. e.,* wollastonite is capable of dissolving about $\frac{17}{83} = 20$ per cent of its own weight. This series of solutions is interesting from the fact that the inversion-point of pure calcium silicate (1,190°) appears to be raised 100° in the most concentrated solutions by the addition of $MgSiO_3$. This is probably largely, if not wholly, an *apparent* rise in the inversion point due to viscosity, for, as is well known, an inversion-point should be raised only when the concentration of the solution below the point is greater than that above, while here there is a rise in the weaker solutions which suffer no change in concentration when they invert. Again, the concentration of solutions just below the inversion point can not be determined with accuracy on account of the difficulty of establishing an equilibrium in solid silicate solutions.

(*b.*) Diopside dissolves about 60 per cent of its own weight, forming a solution which contains 66.5 per cent $MgSiO_3$: 33.5 per cent $CaSiO_3$. This saturated solution is very similar to diopside in all its properties. Its melting-point is only 3° lower; the index of refraction and specific gravity are changed very little, both are a little lower, while the optic axial angle and extinction angle were found to fall about 0.5° for each additional 1 per cent of $MgSiO_3$.

The specific-volume curve consists of three well-defined branches, the first of which is the locus of the volume of mechanical mixtures of pseudo-wollastonite (α-$CaSiO_3$) and diopside; the second, that of the solid solutions of magnesian pyroxene (β-$MgSiO_3$) in diopside; and the third the locus of the volumes of mixtures of saturated mix-crystals just mentioned, and the free magnesian pyroxene. The volume of the solid solutions is *greater* than the sum of the constituent volumes. There is a sharp minimum on the curve at the composition of diopside $CaSiO_3.MgSiO_3$. On account of the presence of minute bubbles in the crystals and the comparatively small difference between the specific gravity of diopside and that of the magnesian pyroxene, the critical points on the curve are several per cent in error.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the third annual report of the present Director, covers the period from November 1, 1907, to October 31, 1908. The regular staff of the Department has remained unchanged throughout the year. As to place, it seemed that greater efficiency would be secured, from June to September, by removing to a cooler climate than that of Washington, as had been done in the previous summer by removal to Cambridge and Boston. Accordingly we removed to Ithaca, where, through the kindness of President Schurman and the professors of history, we were given the amplest use of the library of Cornell University and adequate office accommodations.

The general plans of the Department continue to be as set forth in my first annual report. The Department is still mainly concerned with publications intended to aid investigators in American history without trenching on ground already occupied or likely to be occupied by local agencies. These publications fall into two classes, the one that of reports, aids, and guides—the other, that of textual publications of documents. Under these two heads, and a third relating to the miscellaneous activities of the Department, the work of the past year and the plans for 1909 will be successively considered in this report.

WORK OF THE PAST YEAR.

Reports, Aids, and Guides.—In February the Institution published the second edition of Van Tyne and Leland's "Guide to the archives of the Government in Washington." Greatly enlarged by more detailed researches, especially in the cases of the Department of State, the Post-Office Department, and the Navy Department, it makes a volume of 327 pages, as over against 228 pages in the first edition, having also a much fuller index than the latter. Seldom has the sum total of any Government's archives, of equal extent, been so comprehensively and fully described before. Beside its use by private historical investigators, the portions of it relating to the different Departments at Washington have been of much use to their officials, some of whom have expressed high appreciation of the work. Data supplementary to it, when received, are systematically filed for subsequent use, the Government archives in Washington being constantly regarded as one of the Department's main objects of attention.

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* Address, Bond Building, Washington, District of Columbia. Grant No. 477. $20,000 for investigations and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, and 6.)

The next most important work of the year has been the printing of the "Guide to the manuscript materials for the history of the United States to 1783, in the British Museum, in minor London archives, and in the libraries of Oxford and Cambridge," by Prof. Charles M. Andrews, of the Johns Hopkins University, and Miss Frances G. Davenport, of our staff. The manuscript (Miss Davenport's portion having taken a long time to complete) was sent to the printer in March; the last page-proofs were received in August. The nature of the book required an exceptionally full index. This at the end of October is in the press, and the volume should appear before the end of the calendar year. I do not hesitate to say that, with its companion volume on the Public Record Office, by Mr. Andrews alone, it constitutes a work that will do more to advance the study of the English colonies in America than any previous book ever written. Of the present volume somewhat more than half is the work of Professor Andrews, the product of systematic labors beginning in 1904. He has listed and described all the manuscript materials for the history of the United States prior to 1783 which are to be found in the British Museum, the Privy Council Office, the Bodleian Library, and the libraries of the Oxford and Cambridge colleges. Miss Davenport has dealt in a similar manner with the manuscripts of the House of Lords, Lambeth Palace, Fulham, the Royal Society, and many minor repositories. The whole constitutes a volume of about 500 pages, embracing a vast amount of detail, worked out with unsparing labor by both authors.

Mr. Andrews's similar volume on the materials for American history in the Public Record Office has been held from completion, as was explained in my last report, by the thoroughgoing changes of classification undertaken among the papers of that great repository. The process will continue to delay Mr. Andrews till next summer. During the intervening year, however, he has done what could be done, on the basis of information sent him from London, toward reshaping the materials of his Guide into accordance with the new conditions. Naturally this is a lesser part of the work of rewriting than that which must be performed on the spot.

Mr. Waldo G. Leland, of our permanent staff, has been in Paris since the date of the last annual report, engaged in preparing, on a plan having a general similarity to that of Mr. Andrews's volumes, a Guide to the materials for American history in the archives and libraries of that city. The officials in charge seem to have given him every facility, and he has examined with care the chief collections in which papers relating to the history of the United States or Canada are to be found. These are the Archives Nationales, the archives of the Ministries of Foreign Affairs, War, and Colonies, and the Bibliothèque Nationale. In the case of the Bibliothèque Nationale, he has had, through the kindness of Dr. A. G. Doughty, C. M. G., archivist of the Dominion of Canada, the aid of the materials which Dr. H. P. Biggar, Cana-

dian record agent, had prepared during many months of work in that library. Mr. Leland's inquiries have extended to maps as well as to written documents. He has nearly finished work in the five chief repositories mentioned above. Meanwhile he has, by my permission and often at my request, been of great service to American states, historical societies, and individuals who have had inquiries or searches to make in Paris, the proper conduct of which would be greatly advanced by the advice and aid of one who was on the spot and whose judgment in archive-matters could be implicitly relied on. Mr. Leland also represented the Department at the sessions of the International Historical Congress at Berlin.

Professor Bolton's period of work in Mexico, for the preparation of a general guide to the unprinted materials for United States history, to be found in that country, was to extend from July, 1907, to near the end of September, 1908. Till the end of June he was occupied with work in the Federal city. He finished a systematic examination of the great stores of manuscripts preserved in the Archivo General y Publico, in the Biblioteca Nacional, in the library of the Museo Nacional, and in the general archives of the Secretariates of War, Justice, Relaciones, Fomento, Gobernación, and Hacienda. Through the good offices of our Secretary of State and of our Ambassador in Mexico, and the especial kindness of Señor Creel, Mexican ambassador in Washington, the officials of the Mexican Government have been disposed to render all proper facilities for Professor Bolton's work. He has found the various governmental archives extraordinarily rich in material for all periods of United States history, and for the history of all parts of the country which were formerly subject to Spain—Texas, New Mexico, Arizona, and California. A partial account of these riches, mostly unknown to scholars hitherto, was presented in a paper entitled "Material for southwestern history in the Central Archives of Mexico," which he read at the meeting of the American Historical Association in Madison in December, and which was printed in the April number of the American Historical Review.

Before leaving the City of Mexico, Mr. Bolton examined beside the Federal archives, those of the Ayuntamiento, those of the secretary of the archbishopric, those of the Congregation of San Felipe Neri, and those of the College of Santo Domingo. Both in the capital and in the provinces entrance to ecclesiastical archives has been greatly facilitated by the letters written on Mr. Bolton's behalf by His Excellency the Apostolic Delegate in Washington and by His Eminence Cardinal Gibbons.

At the beginning of July Mr. Bolton went to Querétaro, to begin a similar exploitation of provincial archives. On the one hand, it was desired that he should examine the governmental archives to be found in old provincial capitals of northern Mexico, from which portions of the United States had anciently been ruled; on the other hand, it was expected that several ecclesias-

tical archives in the same region would be found to contain extensive records of missionary activity and observation in our Southwest. These desires and expectations have been realized to a gratifying extent. At Querétaro Mr. Bolton found most in the archives of the Franciscan College of Santa Cruz; at San Luis Potosí, in the general archive and that of the Department of Justice, the latter containing the remaining papers of the old intendancy-general of San Luis Potosí; at Guadalajara, in the archives of the various departments, especially that of justice, in the Archive of Instrumentos Publicos, in the public library, in the archive of the Ayuntamiento, and in those of the secretary and *cabildo* of the archbishopric. At Zacatecas, his finds were chiefly in the College of Guadalupe; at Chihuahua, in the archives of the State. He devoted the remaining available portion of September to the archives of Parral and Santa Barbara, and to those of Durango and Saltillo. Resuming his work at the University of Texas on September 20, Mr. Bolton had left, of the provincial archives of the Mexican Republic important to our purposes, only a few of those nearest to Texas and accessible in short vacations.

The appointment of Prof. Carl Russell Fish, of the University of Wisconsin, as a Research Associate of the Carnegie Institution of Washington for a period of fourteen months beginning in July, 1908, has made it possible to undertake, under the auspices of this Department, similar searches in the archives and libraries of Rome and the making of a similar inventory of the manuscript materials which they contain for the history of the United States and Canada. During the months before Professor Fish's departure, pains had been taken to establish favorable relations with those who might aid his work in Rome; indeed, many such persons had at the time of the Director's visit to that city in 1906 assured him of their disposition to help any agent who might be sent for this purpose by the Department. The Department of State has been so good as to instruct our Ambassador in Rome to further Professor Fish's mission. It is hoped that, beside the Vatican and Italian archives and the various libraries, he may, through the kind offices exercised on our behalf by His Eminence Cardinal Gibbons, be permitted to extend his researches to the archives of the Congregation of the Propaganda, important for American history but not ordinarily accessible. Even without this, however, the harvest should be a rich one.

Before sailing, at the end of June, Professor Fish grounded himself thoroughly in the literature of the Roman archives, and conferred at length with the Director in Ithaca. Arriving in England, he examined the archives of the Jesuits at Stonyhurst and the Roman transcripts at the Public Record Office. In Paris he made an inspection of similar papers at the Bibliothèque Nationale and of the Napoleonic inventories of Roman archives. At the International Historical Congress in Berlin, and elsewhere on his course to

Italy, he received valuable advice from those expert in the use of Roman archives. At Turin he took notes of the materials for the history of the United States in the archives of the Kingdom of Sardinia, and at Florence in those of the Grand-Duchy of Tuscany. Early in September he began work in Rome.

Each of these gentlemen occupied in foreign searches has sent monthly reports of progress to the Director.

Professor Allison, during his college vacation, brought into final form for publication nearly all the data collected by him for the proposed inventory of Protestant manuscript materials for the religious history of the United States. The original plan contemplated simply the listing of those which were to be found in the archives of religious denominations and missionary societies and in the libraries of theological seminaries and denominational colleges. During the past year the scheme has been enlarged by the inclusion of the chief public libraries also.

The list of Spanish transcripts has been enlarged only by the addition of those preserved in Washington itself. The proposed calendar of papers in Washington offices relating to the territories has also made less progress than was expected. Dr. Jernegan, occupied with another research, described below, was not able to begin this task till about the middle of May, when but six weeks of his term of service remained. In that time he made a good beginning with the territorial papers in the Bureau of Rolls and Library in the Department of State.

Textual Publication of Documents.—Dr. Burnett has completed his list of letters of delegates to the Continental Congress and Congress of the Confederation which are already in print. He has also finished the examination for this purpose of all the public manuscript collections which are to be examined in Washington and in South Carolina, while agents locally employed have completed in a similar sense those of Massachusetts and Rhode Island. The last-named have been copied. Indications respecting the portions of the others to be copied are filed on cards in such a manner that copying can be begun at any time, and will probably be begun this autumn, since the necessary data have been gathered from the public repositories of Washington and of all but four of the original states. It is roughly computed that, in the intended publication, the amount of new material will be at least twice that of the material previously known.

Miss Davenport has spent the period from February to July, and the month of October, in the preparation of introductions to the texts she has collected for the proposed volume or volumes of treaties between foreign powers bearing on American history.

The work upon the American Proceedings and Debates in Parliament has been advanced along several lines. First, the scope of the project has been more exactly defined in respect to such matters as British commerce, duties, bounties, drawbacks, piracy, and Atlantic fisheries, the endeavor being made to frame such instructions as will lead to the inclusion of whatever directly or by reasonable implication relates to the history of the American colonies, while excluding that which applies to America only as it applies to the whole British Empire. Secondly, Dr. Walter F. Dodd, taking up the work upon the journals of the House of Commons at the point at which it was left by Dr. Bowman, has continued to the end of volume 34 and to the year 1774 the process of copying or listing for the copyist (copying in the case of the brief entries, listing in the case of the longer) those portions of the text of the journals which are to be printed in the proposed publication. Thirdly, Dr. Jernegan perfected a remarkably complete list of all those printed books and manuscripts which contain or are asserted to contain reports of any debates in Parliament. Fourthly, Prof. W. R. Manning, of the George Washington University, working with this list as a basis, has examined a large portion of the printed books contained in it which are to be found in the Library of Congress, and has noted from them, in form suitable for the guidance of a copyist, all those passages which contain debates relating to America, and which, after editorial criticism and comparison of all available texts, may be used in the proposed compilation. These three investigators have worked in agreement as to principles of inclusion and exclusion, and in frequent consultation, to insure a unified product.

Miscellaneous Operations.—As heretofore, the editing of the American Historical Review has been carried on in the office of the Department and by its staff. Mr. Leland has prepared the annual summary of American historical progress appearing in the "Jahresberichte der Geschichtswissenschaft." He has also been engaged to prepare hereafter a somewhat similar biennial survey for the Revue Historique.

The Director has given some time to the supervision of an annual bibliography, Writings on American History, 1906, compiled by Miss Grace G. Griffin, and continuing the volume "Writings on American History, 1903," published by the Carnegie Institution. He has believed it to be distinctly a part of his duty to assist the American Historical Association by taking part in the work of its special committee on cooperation among historical societies in the exploitation of foreign archives, by acting as general editor of its series of "Original narratives of early American history," by preparing the program for its approaching annual meeting, to be held in Washington and Richmond, and by assuming *ad interim* the duties of the secretary of the association, the latter having resigned.

The Director has felt it to be still more important to take part, as secretary, in the work of the committee on the documentary historical publications of the United States Government, appointed by the President of the United States, under the chairmanship of Mr. Worthington C. Ford, and acting under the committee on Department Methods. That subcommittee, composed of some of the most competent members of the American Historical Association, has undertaken a task of great importance to the future of historical work in the United States—after surveying the long but haphazard series of Government historical publications and estimating as well as possible the present and future needs of the historian, to frame a scientific plan in accordance with which the publication of documentary historical materials by the Government may go forward in a systematic fashion, and one worthy of the importance of the nation's history. The report of this committee will be completed before the end of the present year. If its recommendations are in substance adopted, it is not too much to say, in view of the magnitude of the Government's resources and operations, that some of the most important interests of American historical scholarship will be immeasurably advanced. The plans of my predecessor, Professor McLaughlin, to secure a more adequate publication of the diplomatic correspondence of the United States, plans set forth in an early publication of the Carnegie Institution, will be taken up into, and it is hoped realized in, this more comprehensive project.

During the past year, as in previous years, I have on occasion accepted invitations to lecture on the work and plans of the Department—this year twice, in November at the University of Wisconsin, in August at Cornell University.

Mr. Leland, in Paris, has amiably undertaken many services on behalf of American historical societies and workers, especially for the Mississippi Department of Archives and History, the Missouri Historical Society, and the Wisconsin State Historical Society.

In Washington the members of the Department have spent no small amount of time in rendering such assistance. The copying of portions of the Schoolcraft papers in the Library of Congress and Smithsonian Institution, which has been going on for three years under our direction, for the benefit of the Michigan Pioneer and Historical Society, has now been completed. Other searches and copies have been made for this society, for the Illinois State Historical Library, for the Iowa Department of Archives and History, and for the Virginia State Library, as well as for various individuals. Our practice has been to expect them to pay for copying and for searches occupying a great amount of time, but not for minor searches.

Letters of inquiry as to historical papers in Washington or other matters have, as in previous years, been answered with much freedom.

PLANS FOR 1909.

No entirely new plans for the coming year are proposed. The program laid out in my first annual report provides an ample series of projects, and experience shows how much longer it takes to execute plans properly than to frame them. Continuance of undertakings now in progress is clearly indicated as the expedient and sufficient program for 1909.

Reports, Aids, and Guides.—In June, as soon as he is able to do so, Mr. Andrews will repair to London, to finish on the spot the rewriting of his "Guide to the materials for the history of the United States to 1783" in the Public Record Office. He has furnished me with a detailed statement of what remains to be done. It will occupy three months. After his return to Baltimore he will put the volume into its final shape as soon as is practicable.

Mr. Bolton will arrange his Mexican material for publication as rapidly as possible after his return to his academic duties at Austin. When opportunities for brief absence occur, he will visit and examine those remaining archives of northern Mexico, near Texas, which have not yet been included in his work, and will incorporate the results of these supplementary searches into his book.

Mr. Leland, after several months of work in Paris, came to the conclusion that the nature of the manuscript material for American history to be found there admitted of two forms of inventory—one which could be completed far within the limits of his time in Paris (14 months), the other and much more useful form one which could not possibly be completed without the expenditure of some 5 months more. This is owing to the fact that, while some parts of the material lie in continuous masses of related matter, resulting from continuous administrative procedure and admitting of succinct description, much the largest part consists of single papers scattered through masses of other matter, and not to be dealt with in a manner at all useful to the reader save by outright listing. Moreover, nothing short of listing in these parts can enable the book to take account, as it can and should, of the documents in French archives which have been printed or of which copies exist in the United States. The difference between the two forms of inventory is approximately represented by the difference between Mr. Shepherd's Guide to the chief Spanish Archives and Mr. Andrews's Guide to the British. There can be no question that the latter is to be preferred, unless, as in the Spanish case, the enlargement would, on account of peculiar conditions, lead to several years' delay. Accordingly it has been determined that Mr. Leland, returning to Washington early in December and remaining here till June, occupied with other work that ought not to be postponed and with the editing of the Parisian material thus far accumulated, should go again to Paris in June for four months to finish his work in accordance with the larger plan now assigned to it.

Mr. Fish will continue in Rome till the end of August, occupied with the preparation of a volume which shall describe the materials for the history of the United States to be found in the Vatican archives, in those of as many as possible of the papal congregations, in those of the kingdom of Italy, and in the various libraries of the city. Whenever material which under normal modern conditions would be deposited in the central archives of the papal or royal government is found to have strayed to other cities, as in the case of the Farnesi archives at Naples, he is authorized to pursue it thither if there is prospect that, in records, in registers, or in the correspondence of secretaries or nuncios or other ecclesiastics, it contains papers relating to American history.

It is desired next to set on foot an archive-mission in Germany. If the plan be approved by the Board of Trustees, Prof. Marion D. Learned of the University of Pennsylvania, editor of the official organ of the German-American Historical Society, will proceed to Germany in February, to spend six months in researches on our behalf. Important reasons exist for making a German mission the next in our series. If it were simply question of the diplomatic archives of Prussia and the other German States, or in general of the history of the public relations between those states and the United States, it is probable that the German mission would be postponed to others. For instance, the archives of the Netherlands contain much interesting material, long familiar to scholars by reason of the admirable reports made 60 years ago by John Romeyn Brodhead, but increased by modern additions, upon which the Department has a valuable report from Prof. William I. Hull of Swarthmore College. Much could be said in favor of an early dealing with the British archives for the period since 1783 and their documents for the history of diplomatic relations between Great Britain and America. A fuller treatment of the Spanish archives must some time be undertaken; and, to say nothing of the minor countries of Europe, the archives of Canada and its provinces and of the British West Indies have strong claims to attention.

But in the case of Germany we have not simply the historical problem of its public relations to the United States, but the much more important subject of the history of the great German migration to America in the seventeenth, eighteenth, and nineteenth centuries. Next after the British movement to North America and the Spanish to South America, this has been the greatest migration of civilized mankind which history records. It has probably given to the United States at least a sixth of its present blood. If historians are not to be occupied solely with constitutional and political history, so vast a social movement deserves that researches much more systematic than any heretofore undertaken should be brought to bear upon the materials for its history. Those materials are to be found in provincial and local archives, in those of noble or formerly reigning families, and in the libraries of cities, ecclesiastical

bodies and old universities. With many of these deposits Professor Learned is already familiar. Six months' work should make possible the preparation of a guide to at least the majority of them.

Whether after the completion of Mr. Allison's inventory of the Protestant religious archives it will be possible immediately to undertake a similar descriptive list of the materials for American religious history in the archives of the Catholic dioceses, orders, and colleges, is uncertain; nor is it equally needful, Catholics having, proportionately, done much more to illustrate the annals of their church by documentary publication than have the Protestant denominations. It should be easily possible within the year to complete and publish the lists of documents derived from the Spanish archives and relating to American history, which have been printed or of which transcripts exist in the United States. As much as possible will be done toward carrying forward the calendar of documents in Washington archives relating to the territories.

Texts.—Miss Davenport's main task for 1909 will be the completion of the volume or volumes of treaties, already referred to; Dr. Burnett's, that of the series of letters of delegates to the Old Congress. The scope of both undertakings was described in my last annual report. The pieces of work still necessary toward the finishing of the latter are: the searching of the archives and chief libraries of New York, New Jersey, Pennsylvania, and Maryland; the inspection, so largely as may be permitted, of the collections of letters of members of the Old Congress which are in private hands; the copying of the unprinted letters found; the collation with the originals, when accessible, of the texts of those already in print; and the labor of annotation.

It is impossible to predict just how large a portion of the work requisite for the proposed series of American Proceedings and Debates in Parliament can be accomplished within the year 1909. The search of the journals of the British House of Commons can certainly be completed; perhaps also that of the journals of the House of Lords and of the Scottish and Irish houses, and the search for reports of American debates in printed books accessible in American libraries. Copying of journal matter can be begun. Beside rarer printed sources, in the British Museum and elsewhere, Dr. Jernegan has located a great variety of manuscript reports of debates extant in England, which must ultimately be searched for American material. Of Irish parliamentary debates, apart from the one published collection, he has discovered the only extensive record, and a very important one, in the Division of Manuscripts in the Library of Congress.

Miscellaneous Operations; Department Building.—Activities similar to those described under this head above, in the report concerning the past twelve months, must be expected to be maintained in 1909. Aside from these, the main matter to be mentioned in this concluding section of this report is

that of the need of an adequate building for the Department. Its present quarters are unsatisfactory in location—noisy, dusty, and remote from the Library of Congress. Our chief work, outside that done in our rooms, is prepared in that library, and most of our staff, except the Director and those occupied with clerical work, spend most of their time in it and in going to it and from it. There would be a great gain in the economy of time, in quiet, in efficiency, in opportunity for mutual consultation, in organization, unity and harmony of work, if we could have an adequate building in the immediate neighborhood of the Library of Congress. Our present location loses the one merit it has had, that of nearness to the administrative offices of the Institution, whenever the latter, presumably at some time in 1909, are transferred to their new building on Sixteenth Street.

But adequate quarters, and especially fireproof quarters, for such an institution can apparently not be rented in the neighborhood of the Library of Congress. Fireproof quarters, however, we undoubtedly ought to have, since for five years we have been, at much expense, accumulating data which ought not to be subjected to any avoidable chance of destruction, and shall in future years accumulate much more. Therefore I urge that steps be taken to provide the Department with an adequate building of its own, on a piece of ground situated in the locality indicated, and affording sufficient space to secure proper light, ventilation, and protection from fire. So vital is such accommodation to the prosperity of the Department that I make this by far the chief recommendation of the year, hoping that by this time there is sufficient confidence in the future of the Department to make the request seem reasonable and appropriate. If the proposal is in general terms regarded with favor, I shall be happy, if desired to do so, to make suggestions respecting details. It is true that our requirements are on the whole simple; yet our work has its peculiarities, and in the construction of a multitude of buildings for American historical societies and American and European archives, and of such buildings as the John Carter Brown Library, that of the Hispanic Society, and others, a considerable amount of experience applicable to our peculiar problems has been developed.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

From October 15, 1907, to February 27, 1908, the Director was absent in Europe making a study of Medusæ in order to obtain information required in the writing of a work upon the Medusæ of the world. During October and November these studies were carried out at Mousehole, on the coast of Cornwall, England, and during the winter at the Naples Zoological Station, where the director, Geheimrath Professor Dr. Anton Dohrn, and his able corps of associates, were untiring in their generous efforts to place all the facilities of this greatest of all marine laboratories at our disposal, and it is with a feeling of enduring gratitude that I now avail myself of the pleasure of expressing my sense of indebtedness to the intelligent kindness of these gentlemen, to whose efforts the success of my studies at Naples is due.

Sixty-seven species of European Medusæ were figured and studied during this visit to Europe; and I was also enabled to consult certain rare publications not found in American libraries.

The yachts *Physalia* and *Sea Horse* remained moored in the Miami River, Florida, throughout the winter and were thoroughly overhauled, so as to be ready for service early in April.

Dr. T. Wayland Vaughan, of the U. S. Geological Survey, was then taken upon a cruise the object of which was to study the biological conditions of the coral reefs of the Florida and Bahama region. Landings were made upon many of the Florida coral islands, as the *Physalia* and the *Sea Horse* cruised down on the inner side of the keys through the Gulf of Florida from Miami to Key West. Excursions were also made across the Hawk Channel, and beyond the Gulf Stream to the Bahama side. Dr. Vaughan was untiring in his zeal to avail himself of every opportunity in these studies, and he discovered a number of new and interesting facts concerning the associations of the various species of corals with reference to situation upon the reefs, depth, strength of currents, prevalence of silt, purity of water, etc., as well as certain important matters in respect to the origin and structure of the reefs. Upon arrival at Tortugas he proceeded to obtain the planula larvæ of certain corals, which are now being reared under observation in natural conditions, thus giving an accurate idea of the normal duration of the free-swimming stage, rate of growth, etc. His research, which is unique in its character, must be carried on for several years before decisive results can be obtained.

* Laboratory located at Dry Tortugas, Florida. Grant No. 478. $13,000 for investigations and maintenance. (For previous reports, see Year Books Nos. 3, 4, 5, and 6.)

A

B

A. The new veranda at Tortugas, 1908.

B. Cages for beetles for Dr. Tower's experiments.

Another research which will demand several years for its completion is that of Prof. W. L. Tower, whose well-known work upon the experimental production of new characters in insects is to be continued at Tortugas. Dr. Tower brought to the station a supply of food plants, which are now being reared under the cover of large cages of fine-meshed wire-netting, and which will thus be ready in 1909 for the introduction of the beetles upon which he expects to experiment. The warm, uniform temperature, excessive aerial moisture, and the perfect isolation of the Tortugas render the station an apparently ideal situation for some of Dr. Tower's experiments.

It is the aim of the Laboratory to afford unrivaled facilities for the prosecution of researches such as have not hitherto been conducted within the tropics. Biological research in the torrid zone has been practically confined to the collection of specimens, which have then been brought into temperate regions for study, and almost nothing has been done in the study of living forms within the tropics themselves. Thus we know but little of the habits, physiology, embryology, laws of heredity, etc., of tropical animals and plants, although some of these afford opportunities for study not presented by the forms of the temperate regions. The Laboratory is therefore devoting its energies largely to the encouragement of researches into the laws governing life, rather than to the systematic collection of groups which have already been extensively studied.

The laboratory is placed upon the most inaccessible island along the entire range of the Atlantic coast of the United States, but due to the kindly aid which has been so cordially rendered to us by Commodore William H. Beehler, U. S. N., Commandant of the United States Naval Station at Key West, it has been found possible to maintain the station in a state of full efficiency in all respects.

This isolation greatly increases the expense of maintaining the Laboratory; indeed no agency in our country other than the Carnegie Institution could succeed in so doing. On the other hand, the absolute freedom from interruption is a blessing unknown elsewhere in our busy land. The investigators of the Laboratory have been chosen from among the most promising of our country's productive students, but the success which has been achieved by them at Tortugas is due in nearly equal measure to their assurance of freedom from interruption.

The Laboratory was placed upon the Tortugas on account of the proximity of the warmest and purest water of the Gulf Stream, with its rich pelagic life and luxuriant coral reefs, and on account of its freedom from mosquitoes and tropical diseases, but the most unique of our advantages is that of isolation.

During the season of 1908 a veranda 15 feet wide was constructed to cool the air which enters the Laboratory from the eastern side. This veranda is provided with a concrete floor which is surrounded by a moat filled with

water, thus giving an ant-proof area most desirable for certain experiments. A new windmill was installed especially to pump pure sea-water into the aquarium tanks, and improvements were also instituted by virtue of which all refuse is quickly carried far out to sea, thus preventing the possible introduction of typhoid, dysentery, or other diseases which are a menace to the majority of tropical places.

For the production of the best work in research it is essential that students be surrounded by things attractive as well as interesting, and indeed a large measure of the success of the Naples Laboratory is due to the unrivaled beauty and historic fascination of all that surrounds it. It is exceedingly difficult to maintain many plants upon a small island every grain of the soil of which is but the fragment of some marine shell or coral, and over which the spray dashes in clouds in every storm; yet it is the hope of the Laboratory to one day surround the buildings by a garden which will render the station attractive to botanists as well as to zoologists.

The following investigators studied under the auspices of the Department of Marine Zoology during the past season:

Dr. R. P. Cowles, Johns Hopkins University, June 26 to July 22.
Mr. Davenport Hooker, Yale University, July 10 to 22.
Professor Edwin Linton, Washington and Jefferson College, June 26 to July 17.
Dr. J. F. McClendon, Missouri University, June 11 to July 8.
Dr. Raymond C. Osburn, Columbia University, June 4 to 27.
Dr. Charles R. Stockard, Cornell Medical College, May 19 to June 17.
Professor W. L. Tower, Chicago University, May 12 to 13.
Dr. T. Wayland Vaughan, U. S. Geological Survey, April 15 to May 13.
Mr. W. S. Wallace, assistant, May 15 to July 28.

Apart from the articles which have been contributed by investigators to the two volumes of researches now in press, the following papers have been published elsewhere during the year:

Jacob Reighard, Michigan University: The photography of aquatic animals in their natural environment. Bulletin U. S. Bureau of Fisheries, vol. 27, pp. 41-68.
Charles Zeleny, Indiana University: The effect of degree of injury, successive injury, and functional activity upon regeneration in the Scyphomedusan *Cassiopea xamachana*. Journal of Experimental Zoology, December, 1907.
H. E. Jordan, University of Virginia: The accessory chromosome in *Aplopus mayeri*. Anatomischer Anzeiger, Bd. 32, pp. 284–295, 1908.
R. Hartmeyer, Natural History Museum, Berlin, Germany: Reisebilder aus Westindien mit besonderer Berücksichtigung der Korallenbildungen. Deutsch. Gesell. für volkstümliche Naturkunde, 1908.
Alfred G. Mayer, Carnegie Institution: A plan for increasing the efficiency of marine expeditions. Science, vol. 27, April 24, 1908. Also: Marine laboratories and our Atlantic coast. American Naturalist, vol. 42, p. 533. Also: The cause of pulsation. Popular Science Monthly, December, 1908.

Dr. Zeleny finds that the medusa confirms his law that the animal with the greater amount of removed tissue regenerates at a more rapid rate than the animal with the lesser amount of removed tissue. Also, that functional activity or inactivity has no apparent effect upon the rate of regeneration. Dr. Stockard's more recent researches also support these conclusions.

The collection made by Prof. Ulric Dahlgren at the Laboratory in 1906 has provided him with certain material the study of which has contributed to the valuable Text-Book of the Principles of Animal Histology, 1908, by Ulric Dahlgren and William A. Kepner.

Before presenting the preliminary reports of investigators who have studied at the Laboratory during 1908, the following brief summary of the results attained may be of interest:

Dr. R. P. Cowles studied the righting reaction of several species of brittle-stars. His observations are very extensive, and have been carried out with care to avoid possible errors of interpretation. He prefers at present to refrain from announcing any conclusions.

Mr. Davenport Hooker discovered that the newly-hatched young of the loggerhead turtle are strongly attracted toward the color blue. They crawl immediately toward a pane of blue glass thrust upright in the sand, or even to a piece of blue paper. They have no preconceived idea of the appearance of the ocean, and will turn away from the sea if it be seen through yellow, red, or green glass. They are attracted toward the ocean solely by the blue color of its waters. Mr. Hooker also finds that the young turtles tend to crawl down-hill, and are attracted by large areas of light of low intensity rather than by small areas of high intensity.

Prof. Edwin Linton continued his systematic study of the parasites of fishes with even better fortune than formerly. He finds that there are very few flesh-parasites in the Tortugas fishes. Also the Acanthocephala and Nematoda are more abundant in northern than in tropical fishes. On the other hand, the Cestodes and Trematodes are fully as abundant in Tortugas as in northern fishes. On the whole, the Florida fishes appear to be relatively free from parasites as compared with northern ones.

Dr. J. F. McClendon studied the habits and feeding reactions of a new species of sea-anemone of the genus *Cradactis,* which walks upon its tentacles. He also found a remarkable Potoniid crustacean which appears to have become convergently modified in structure and habits, so as to closely resemble the common *Synalpheus,* together with which it lives in the cavities of loggerhead sponges.

Dr. Raymond C. Osburn made the first extensive systematic study of the Bryozoa of the shallow water of the Florida region. He found about 50 species, at least 20 of which are new to the North American fauna, or to science. At least 15 species are characteristic of the Mediterranean, and 12 of Australia and the East Indian region. The fauna of Tortugas is decidedly tropical, only 10 species of Bryozoa being found both off the New England coast and at Tortugas. The Bryozoan fauna of Tortugas is much richer than we have hitherto believed it to be.

Dr. Charles R. Stockard finds that in the medusa *Cassiopea xamachana* the rate of regeneration increases in a direct ratio to the extent of injury, in accordance with Zeleny's rule. Dr. Stockard also makes the interesting discovery that the regenerating tissue grows at the expense of the normal tissues of the body, so that the body shrinks in size while the regenerating parts continue to grow rapidly. He calls attention to the important fact that cancerous growths have the same remarkable power to absorb nutriment at the expense of the body as has regenerating tissue.

Dr. Stockard also carried out numerous observations upon regeneration in brittle-stars, but these did not follow Zeleny's rule, but gave indefinite results; one species behaving in a manner exactly contrary to Zeleny's rule and the other being indifferent to it. Dr. Stockard finds that the arms regenerate more rapidly the nearer the cut is made to the central disk. Both the medusa and the brittle-star thus support Morgan's law that the deeper the level of the cut the more rapid the regeneration.

Dr. T. Wayland Vaughan finds that there are at least four types among the Florida Keys.

(1) North of and including Key Biscayne the keys are made of silicious sand with some comminuted shells.

(2) From Soldiers Key to the southern end of Big Pine Key the islands are composed mainly of elevated reef rock.

(3) West of Bahia Honda the keys are composed chiefly of an oolitic limestone.

(4) The Tortugas are composed of comminuted shells and corals, sometimes considerably indurated.

Dr. Vaughan finds that traces of silicious sand extend downward along the Bay of Florida side of the keys to Long Key. He is of the opinion that the Florida oolite has been found in a water-laid deposit probably behind a seaward barrier. He studied the formation of the mangrove shoals behind the keys, and shows that the powerful tidal currents which pass through the openings between the outer keys cause these shoals to trend in a direction perpendicular to the line of the barrier keys themselves. The shoals form in regions of still water along the sides of currents.

Dr. Vaughan is rearing reef corals from the young at Tortugas, and finds that the planulæ may remain afloat for 12 days, thus rendering it possible for them to be carried 800 miles in the Gulf Stream. He is also making a study of the growth of corals found naturally upon the reefs, and is conducting observations upon the environmental factors, associations, etc., of the reef corals. His plan of study is far more detailed, and consequently more accurate than any that has hitherto been attempted.

Mr. W. Seward Wallace collected and studied about 50 species of hydroids at Tortugas. Among them he found the hydroid of *Zanclea gemmosa*, which

is known also from Woods Hole. He also demonstrated that *Pennaria cavolini* from Naples, Mediterranean, is distinct from *P. tiarella* of America. Mr. Wallace labored very assiduously over these studies, and it is surprising that he should have found so many species in a tropical region, for it has been generally assumed that the tropics are poorly endowed with littoral species of Hydroidea.

Alfred G. Mayer discovered that pulsation in Scyphomedusæ is caused by the constant formation of sodium oxalate in the marginal sense-organs. This sodium oxalate precipitates calcium, and thus sets free sodium chloride, which acts as a nervous stimulant. Pulsation is thus due to the constant maintenance of a slight excess of common salt in the sense-organs, over and above the concentration found in the surrounding sea-water. Moreover, the sea-water itself is a balanced fluid neither inhibiting nor stimulating pulsation. The sodium chloride of the sea-water is both a muscular and nervous stimulant, but the magnesium, calcium, and potassium are inhibitors and exactly counterbalance the effect of the sodium, producing a neutral fluid, thus permitting the weak internal stimulus of a slight excess of sodium chloride produced in the sense-organs to maintain the rhythmical pulsation.

The Atlantic palolo worm swarmed at Tortugas on the mornings of July 10 and 19, 1908; the first quarter of the moon being on July 6 and the last on July 19. Worms swarmed normally on July 19 out of rocks which had been maintained in the tideless water of a floating live-car for 6 weeks previous to the day of the swarming.

The writing of a description of all of the Scyphomedusæ of the world has been completed, this being the second volume of a work upon the "Medusæ of the World," the first volume of which is now going through the press.

PRELIMINARY REPORTS OF RESEARCHES, SEASON OF 1908.

Preliminary Report upon the Reactions of Brittle-Stars, by R. P. Cowles, Johns Hopkins University.

During the month of July, 1908, I was enabled to continue my study of the habits of brittle-stars and starfish. Several species of each group were used and these were studied with reference to their reactions to light and contact stimuli. Special attention was paid to the influence of these stimuli, and to the effect of injury on the righting reaction, for the purpose of finding out if possible what it is that determines the manner of righting; and whether there is a tendency for individuals to right themselves on special pairs of rays. Many series of experiments were undertaken, but I wish to continue the work before drawing any definite conclusions from them.

I also began a study of regeneration in *Aplopus mayeri* for the purpose of determining what effect the amount of injury has on the rate of regeneration. These experiments are still in progress.

Report on the Instincts and Habits of Newly-hatched Loggerhead Turtles, by Davenport Hooker, Yale University.

During the summer of 1907 I made some observations on the habits and early instincts of the loggerhead turtle, at the Tortugas Laboratory. This past summer (1908) I repeated these experiments and extended them. As a result of this more thorough investigation, I am led to believe that the deductions I drew last year were partially erroneous, due to lack of sufficient analysis of the environmental factors. At the present time I feel justified in making the following statements as borne out by the facts observed:

(1) The newly-hatched loggerhead turtle moves away from transparent and opaque red, orange, and green, and from green bay-cedar bushes, and moves toward transparent or opaque blue. The colors used were found to be impure, so that their exact value is unknown, but it would seem that an excess of a color produces the effect. This, with a positive reaction to a downward incline, enables the young turtle to reach the sea. This reaction to color probably involves the matter of difference in intensity, but to what extent I am unable to state.

(2) After entering the water, the animal swims out to sea, apparently attracted by the darker blue of the deeper water. The position of the sun is an entirely negligible quantity.

(3) When on the beach in a large sand-pit with level floor, from which pit sight of the bushes and the ocean is excluded, but from which the sun is plainly visible, there is exhibited no tendency to move in any definite direction.

(4) Under a restricted environment, the young turtle is, in addition to its chromotropic response, positively phototropic and responds to a large surface of light of comparatively low intensity rather than to an illuminated point of high intensity, as was found by Dr. Leon J. Cole to be true in the case of many positively phototropic animals having image-forming eyes.

(5) The reactions of the young turtle are not modified by sound or odor of the sea, nor by a tank of sea-water where there is not sufficient quantity to give color.

Preliminary Report on Helminths, by Edwin Linton, Washington and Jefferson College.

Following is a preliminary report on helminths collected at Tortugas in the season of 1908, to which is added a note on the trematodes collected the two preceding seasons:

Source of material.—The fish which were examined for parasites were, for the most part, taken in traps among the coral-heads and in the shallow water on the north shore of Loggerhead Key. A large nurse shark (*Ginglymostomum cirratum*), 2 specimens of spotted stingray (*Ætiobatis narinari*), and 3 species of trunk-fish (*Lactophrys*) were speared by Capt. I. C. Lundblom on the reef near Garden Key. Two tiger-sharks (*Galeocerdo tigrinus*) were taken before I reached the Laboratory. The cestodes which were found in them were preserved in formalin. Again I am obliged to identify this host by means of its parasites (see Year Book of the Carnegie Institution for 1906, pp. 113 and 116; the same, for 1907, p. 114). A stingray which I have recorded under the name *Dasyatis sayi* was also collected before my arrival at the laboratory and was thought to be *Dasyatis hastatus*. It was a female with 2 young. The latter were saved. They appear to belong to the former

species. The spiral valve, which had been preserved in formalin, yielded 5 species of cestodes, all of which were found in the stingray which was examined in 1906. The two species of spotted stingray were the first of the eagle-rays that I have had the opportunity of examining for many years, and it is the first time that I have seen this species.

PARASITES IN FLESH.

In carrying out a line of investigation begun for the U. S. Bureau of Fisheries I made a careful search for flesh parasites in practically all the fish which were examined. The only fish parasites found were in the following fish:

Mycteroperca venenosa.—A few degenerate cysts in flesh near the backbone.

Calamus calamus.—2 small distomes encysted in the flesh of one fish above the backbone; a cestode (*Synbothrium filicolle*) in about the same situation in another.

Acanthocephala.—As in previous years, representatives of this order were found but sparingly. They were found in but 7 of the 32 species of fish which were examined, and in every case few or even only 1 was found. But 1 species was found. This appears to be identical with the one which I have recorded under the name *Echinorhynchus pristis,* which appears to be a species with a southern range. A comparison of the Acanthocephala collected at Bermuda, Beaufort, Tortugas, and Woods Hole justifies the conclusion that the Acanthocephala of marine fishes have their greatest development in species, and particularly in individuals, in northern fishes.

Nematoda.—Like the preceding order, this is rather sparingly represented among Tortugas fishes. Immature, encapsulated forms were found in only 7 species of fish, and very sparingly in all of these except the rockfish (*Mycteroperca venenosa*). This also is in contrast with the distribution of immature nematodes in northern fishes where they are of frequent occurrence on the viscera of a large number of species, and often in large numbers. The immature forms, so far as they have been studied, are characterized by having a cylindrical œsophagus with an elongated bulbous base and a short intestinal diverticulum directed cephalad and lying beside the œsophagus.

Adult nematodes were found in 6 species of fish, but only one or two in each case. For the most part those from teleosts belonged to the genus *Heterakis,* while those from the nurse-shark belonged to the species *acanthocheilus.*

Cestoda.—Encysted and larval forms were found in 11 of the species of fish which were examined this season. In no case were they numerous. It is worthy of note that the larval forms known as *Scolex polymorphus,* which are found in a large number of the fishes of Beaufort and Woods Hole, were found in only 2 of the Tortugas fishes, and but few in each host. These forms represent neither the encysted stage nor the adult stage, but rather a condition of transient residence made possible by their powers of resistance to the intestinal juices of their temporary hosts. The scarcity of these parasites at Tortugas, therefore, which is parallel with what was found to be the case at Bermuda, is dependent rather on the conditions incident to a coral reef than to the real absence of the parasites themselves from the region. In their adult condition they are found in the selachians and in their encysted stages they occur in teliosts, crustaceans, etc. So far as I have studied the

cestodes of the Tortugas selachians I have found that they compare favorably, both in number of species and of individuals, with those of the northern selachians.

Adult cestodes were found in all of the selachians examined. An interesting case is afforded by the spotted stingray, which was examined for the first time this summer. Two genera, *Onchobothrium* and *Tylocephalum*, were found in this ray. The latter genus was established by me in 1890 (Report U. S. Fish Commission for 1887, pp. 806–809, pl. IX, figs. 5–9), and was based on a single specimen. This is a practice which, as a rule, has little to commend it. In this case, however, the scolex was so characteristic that there was no doubt of its unique systematic position. The original specimen came from the cow-nosed ray (*Rhinoptera bonasus*) collected at Woods Hole in 1887. I have had but few opportunities to examine the eagle-rays, and none were seen by me between the years 1887 and 1908 except three in 1889. The genus *Tylocephalum* remained without any other justification than the single specimen collected in 1887 at Woods Hole. Two specimens belonging to this genus were found in one of the spotted stingrays. They are adult, with mature segments, and should furnish important additional anatomical data to our knowledge of this singular cestode. Incidentally, it illustrates an important principle in the distribution of entozoa. Some genera of cestodes are intimately associated with, and often restricted to, either a single genus or a family. This is particularly true for the adult stages. There is thus suggested an interesting series of problems whose solution will rest not only on the working out of the life history of many of the cestodes, but also on a study of the comparative physiology of the various hosts.

Trematodes.—Representatives of this order were found in 21 of the 32 species of fish examined. Twenty-eight species, mostly distomes, were added to the list of the past two years. This number includes those new to the region and those found in a new habitat. Among the former, as of especial interest, may be mentioned an example of *Aspidogaster* found in the porgy (*Calamus calamus*), and a species of *Udonella*, a number of which, together with their ova, were found attached to the bodies of 2 parasitic copepods in the mouth of a gray snapper (*Neomænis griseus*).

I have made a preliminary examination of the distomes collected in the summers of 1906 and 1907, with a view to determining their systematic relations. In this examination I have made use of Professor Pratt's Synopsis of North American Trematodes. That I fail to find a satisfactory abiding place for the majority of these Tortugas distomes is not the fault of the excellent Synopsis, but is to be charged rather to the very large number of genera made possible, and even necessary, by the criteria which have been adopted by modern helminthologists in the dismemberment of the old genus *Distomum*.

Thus the best that I am able to do at present is to report the following list of genera which are either near to, or suggested by, specimens in the collection. This list will be lengthened considerably when the distomes collected in 1908 are added.

Astiotrema.
Azzygia.
Cathænasia.
Derogenes (4 species).
Gasterostomum (2 species).
Glossidium.
Glyphicephalum.
Gymnophallus.
Halicometra (4 species).
Halipegus (2 species).
Hemiurus (2 species).
Lecithaster.
Lecithocladium.
Lepidophyllum.
Liopyge.
Microcotyle.
Opisthorchis.
Psilostomum (2 species).
Progonus.
Pyelostomum.
Stephanochasmus.
Styphlodora.
Tergestia.

In addition to these there are 4 distinct species belonging to the group which I have been recording under the generic name *Monostomum,* but which will have to be assigned to a different genus, or, more probably, to different genera. Furthermore, there are at least 10 distinct species which differ so much from any genera included in Pratt's Synopsis that it can not be said of them that they are even near any of those genera. In some cases it is true that the material is in poor condition, so that the anatomy is incompletely shown. At the same time, the greater part of the material is sufficiently well preserved to show the anatomy satisfactorily.

One of the new forms is an endoparasite of the black angel-fish (*Pomacanthus arcuatus*), which appears to be a new genus of the Tristomidæ, in which the anterior suckers are rudimentary.

From the loggerhead turtle the following genera of trematodes were obtained: *Calcyodes, Cymatocarpus, Orchidasmus,* and one undetermined form which is probably a new genus.

Summary of Investigations at Tortugas, 1908, by J. F. McClendon, University of Missouri.

STUDIES OF SEA-ANEMONES.

During the last half of June and first half of July a number of reef animals were studied, and a reef anemone and 2 crustaceans living in the loggerhead sponge found to be especially interesting.

The sea-anemone *Cradactis* sp. (?) is apparently new and was given to Dr. Hargitt for systematic description. This anemone differs in habits from all other anemones I know of, in being able to crawl on its tentacles. Therefore its general behavior was studied so that comparison might be made with the behavior of other anemones. The outward form is similar to the type species of *Cradactis* in the presence of branched tentacle-like structures or "fronds" outside the ordinary tentacles. These fronds are so shaped and colored as to give the appearance of sea-weed. The animal lives in cavities in coral heads having openings to the exterior through which the fronds are protruded during the day (they being contracted at night). When crab-meat is held near the cavity containing the *Cradactis* there is no response until the meat touches the fronds, when the tentacles are extruded, grasp the meat, and carry it to the mouth. Sections show the fronds to be supplied with nematocysts and mucus glands, and they may catch food, but they do not carry it to the mouth. To observe the further feeding reactions, the anemones were taken out of the coral and placed in dishes of sea water. When a bit of crab-meat is placed on the end of a tentacle it adheres, and the tentacle and one or more adjacent ones are bent over, and the food placed on the mouth. Immediately many or all of the tentacles are pressed on the food, and the mouth widens and swallows it.

Cradactis sometimes swallows filter paper placed on the middle of the tentacles or on the disk, but not when placed on the tips of the tentacles. Possibly in the last case less area is stimulated. The filter paper is disgorged within ten minutes. India-ink shows ciliary currents running toward the tips of the tentacles and fronds, and on the disk toward the mouth. The animal is disturbed by light falling on its base, and may move a short dis-

tance with snail-like movements. But soon the tentacles catch hold of the substratum on all sides, and with considerable writhing the anemone loosens the base and walks on its tentacles in an inverted position to a new place, where it rights and attaches itself. Small crabs live in the cavities with the anemones and crawl over them with impunity, as the anemones are not strong enough to swallow the crabs. It is not probable that the fronds serve as a protective function, but they may serve as lures for catching prey.

Stoichactis helianthus.—Another reef anemone, *Stoichactis helianthus,* was found to crawl with snail-like movements similar to *Metridium.* It reacts negatively to light falling on its base.

STUDIES OF CRUSTACEA.

Synalpheus lævimanus longicarpus Herrick lives in the cavities of the loggerhead sponge. The animals occur in such numbers that 200 c. c. of them could be obtained from a sponge 2.5 feet in diameter. In the same sponge would be found 4 or 5 small Amphipods and about 6 to 12 specimens of an undetermined Potoniid. The Amphipods seemed to go into small cavities beyond the reach of the Alphei, but the Potoniids were similar in size and shape to the Alphei, and had very similar habits in so far as these could be investigated. Whereas *Alpheus* has the first pair of thoracic legs greatly and asymmetrically developed, the same is true of the second pair of thoracic legs of the Potoniid. In both animals the largest claw can be closed with such rapidity and force as to produce a loud snapping sound (this is true of the smaller claw also in the Potoniid). The animals will eat crab-meat, but as only 2 or 3 out of about 1,000 were seen to come outside of the sponge (at night) it is probable that the large claw is for defense, and that the animal feeds on the sponge or food brought in by the currents in the sponge. The striking similarity of these two species of widely separated genera might lead one to suspect a case of protective mimicry. As a matter of fact, the Alphei are not always very friendly to one another, and as the Potoniids are equally well, and possibly better, armed and can not be assailed by great numbers in the narrow cavities of the sponge, it seems hardly necessary for them to deceive the Alphei in order to exist. I think we have here a case of convergence in structure which has caused the animals to become adapted to the same mode of life.

Preliminary Report on Bryozoa of the Tortugas, by Raymond C. Osburn, Columbia University.

It was the privilege of the writer to spend the greater part of the month of June, 1908, at the Tortugas Laboratory, collecting the Bryozoa of the region. No report has ever been made upon shallow-water collections from the southern part of the Atlantic coast of North America, although Smitt's excellent paper on the Floridian Bryozoa collected by Pourtales (Kongl. Svensks Vetenskaps-Akd. Handl., 1872–3), probably covers the deeper-water forms fairly well. For these reasons my attention was directed to shore and shallow-water collecting, as promising the most interesting results.

The piles of the U. S. naval docks at Garden Key, the moat surrounding old Fort Jefferson on the same key, and the drift on the shore of Loggerhead Key were carefully worked. Material was collected at low tide on the reefs.

Numerous dredgings were made in shallow water, down to 20 fathoms, with the *Sea Horse* and *Physalia*. No attempt was made to go beyond the shelf surrounding the keys; in fact, practically all the collecting was done in less than 12 fathoms, since it was observed that below this depth the character of the fauna rapidly approaches that of the deeper water.

The conditions for the growth of Bryozoa are not particularly favorable, owing to the great amount of coral mud which settles on everything in quieter water, while in many places the shifting coral sands prevent the growth of any sessile form of life. Material taken from the piles and the moat was usually so covered with coral mud as to be unrecognizable until thoroughly washed under a tap, and in the case of Ctenostomes it was found necessary to treat with weak acid to dissolve away the layer of calcareous mud before the characters could be ascertained. The cleanest and best-developed specimens as well as the greatest number of species were dredged on sponge beds at 5 to 10 fathoms. Many species were found growing on sponges.

The writer has not had opportunity to study the collection carefully, consequently the following account of the species is merely tentative.

Fifty or more species were taken in the limited region above mentioned. Of this number only 30 have as yet been recorded from the West Indian fauna. The 20 or more remaining species are nearly all new, at least to the North American fauna. How many of them are as yet undescribed remains to be determined.

ENDOPROCTA.

Barentsia (*Ascopodaria*) *discreta* Busk. This, the only species of endoprocta taken, has hitherto been recorded only from Tristan da Cunha (*Challenger*), but the writer has taken it also at Woods Hole, Massachusetts, and Beaufort, North Carolina. No endoprocts are mentioned in Smitt's paper.

ECTOPROCTA.

The Ctenostomes are well represented by 5 genera and at least 6 species. All of these species and 3 of the genera are new to our east coast fauna.

Zoobotryon pellucidus Ehrenberg. This fine species forms large colonies on the piles and in the moat at Fort Jefferson.

Cylindrœcium sp. occurs in great abundance, sometimes covering shells and algæ with a dense coating of the erect tubes.

Bowerbankia caudata Hincks occurs on piles and down to 10 fathoms.

Amathia spiralis Lamouroux (?) occurs plentifully in the dredgings, and a smaller species with it.

In Pourtales's collection Smitt found only 1 ctenostome, and it was not in condition to identify beyond the genus *Serialaria*.

Of Cyclostomes only a single species, *Crisia ramosa* Harmer (?), occurs among my material, while Smitt recorded 10 species belonging to 7 genera, all from deeper water.

The Chilostomes are, as everywhere, the predominant group, and they pass through all the usual types of growth from creeping and incrusting to various erect forms. The following genera have been noted: *Ætea, Catenaria, Farcimia, Scrupocellaria, Caberea, Bugula, Beania* (?), *Cupularia, Thalamoporella, Steganoporella, Smittipora, Membranipora, Cribrilina, Microporella, Hippothoa, Schizoporella, Cellepora, Mucronella, Smittia, Lepralia*, and *Retepora*.

Ætea is represented by at least 1 species new to the North American fauna.

Catenaria lafontii Savigny: Both genus and species are new to our fauna.

Bugula: 5 species, none of them reported from eastern North America, and the only one yet identified is *B. neritina* L., of world-wide distribution in warm waters.

Beania (?): A beautiful species growing on the under side of *Cupularia* colonies.

Hippothoa: A species which seems to be the northern *H. divaricata* is not uncommon on shells.

In the other genera mentioned there is nothing especially worthy of note with regard to distribution, excepting possibly certain species which I have not yet studied.

The general character of the Bryozoan fauna is decidedly like that of other warm regions of the globe. For example, I have recognized 15 species as belonging to the Mediterranean and 21 from the East Indian and Australian region, while in contrast, only 10 species of the Tortugas Bryozoa have been recorded from the New England coast, and 7 of these are species of very wide distribution over the North Atlantic.

Preliminary Report on Regeneration Studies, by Charles R. Stockard, Cornell University Medical College, New York City.

A more extensive series of experiments relative to the rate of regeneration in *Cassiopea xamachana* were conducted as a continuation of my researches of the previous summer. Some points not then clearly shown were worked out in greater detail. Experiments to test the possibility of heteromorphic regeneration as a cause of the different growth rates observed from the various regions of bias-cut peripheral strips showed that heteromorphosis was not the cause. My previous interpretation that the rate of regeneration in both directions towards the periphery and towards the disk center varies according to the level of the cut is still held to be correct. Small bias-cut strips, as well as triangular and V-shaped pieces of the medusa disk show great regulatory ability. Such pieces will invariably form circular bodies in the most direct manner. Such small circular bodies pulsate and act very much as an entire medusa disk would.

The chief experiments were conducted with a view of determining the influence of the extent of injury on the rate of regeneration. Sufficient data were obtained to give definite indications regarding this perplexing problem. Fourteen individuals were injured in each of the following ways: The first group had one of their oral-arms cut off at its base, the second to the fifth group, respectively, had 2, 4, 6, and 8 arms similarly cut. We thus have 5 groups of individuals, each group injured to a different degree. Comparing the specific rates of regeneration, we see that the least injured grow somewhat faster than those with 2 arms cut away, the ones with 4 removed arms grow faster than either of the groups less injured, those having lost 6 arms grow still faster, and those from which all 8 of the mouth-arms have been removed regenerate most rapidly of all. This seems to indicate that the rate at which *Cassiopea* regenerates its oral-arms varies directly with the number of arms removed; the more arms cut away the more rapidly will each arm be replaced.

None of the specimens were fed during the experiment, which lasted for 21 days, and all decreased considerably in size. It is important that those

with most arms removed decreased most rapidly, the group having lost 8 arms decreased twice as much as did those from which only 1 arm had been removed. Although the greatly injured animals were decreasing in size so rapidly they produced new arm-buds at the fastest rate. From this it seems that the regenerating tissue has the power to grow and assimilate material at the expense and actually to the exhaustion of the original body-tissues. This suggests the action of malignant growths—tumors and cancers. Such tissues have an excessive capacity to absorb nutriment, and in so doing finally cause the normal body-tissues to succumb. The regenerating arm-buds seem to possess a similarly exaggerated capacity for absorbing nutriment from the original body-parts.

In connection with these experiments on Medusæ, a large series of similar experiments were tried on two species of brittle-stars common on the coral reefs at Tortugas. Great difficulty was experienced in keeping these animals in aquaria, but they lived and thrived in floating live-cars. These cars were divided into small compartments so that the experiments might be separated.

The experiments ran for almost 50 days, and the animals increased in size and regenerated new arm-buds ranging from 25 mm. to more than 50 mm. in length. The two species, *Ophiocoma riisei,* and a grayish form not yet determined, were operated upon in similar manners so as to facilitate comparisons. *Ophiocoma riisei* regenerated faster than the gray species in all cases. Both species regenerate their arms more rapidly when cut close to the disk than when cut at greater distances away. Thus the deeper the level of the cut the more rapidly will the ensuing regeneration take place.

Individuals of both species were selected and divided into groups from which different numbers of arms were removed, all arms being cut at a distance of 1 cm. from the disk. *O. riisei* regenerated its arms at rates entirely indifferent to the degree of injury inflicted. The gray species regenerated its arms fastest when few had been removed, and distinctly slower when many had been cut away. Starfish with 5 arms cut off regenerated only three-fourths as rapidly as those with 1 arm removed and individuals having lost 4 arms regenerated almost as slowly as those with all 5 cut.

These results exactly oppose those obtained from the Medusæ. In both cases large numbers of individuals were used and the regenerated buds were long and easily measured, so that the error in the work is small. Such results indicate that the influence of degree of injury is not universal and may be different in different animals. The different rates shown by the two species of brittle-stars when similarly injured and kept under identical conditions are suggestive in the latter regard.

Geology of the Florida Keys and the Marine Bottom Deposits and Recent Corals of Southern Florida, by T. Wayland Vaughan, U. S. Geological Survey.

GEOLOGICAL STUDIES.

The excavations made during the recent extension of the Florida East Coast Railway, together with the facilities afforded by the boats owned by the Marine Laboratory of the Carnegie Institution offered opportunities for additional observations on the geology of the Florida Keys. I therefore examined many of the keys, beginning with the southern end of the cape imme-

diately east of Miami and extending to Key West. The following is a brief statement of my observations:

New Cut, across the tongue or cape of the mainland east of Miami.—The surface material consists of siliceous sands.

Virginia Key.—The surface of this key, the first of the line of keys, is covered by siliceous sand, with some comminuted shells.

Key Biscayne.—The surface of this key is also composed of siliceous sands with some comminuted shells.

Soldiers Key.—The summit and western side of this key are composed of siliceous sands. Coral-reef rock, composed of heads of *Orbicella annularis, O. cavernosa, Mœandra viridis, M. labyrinthiformis,* and *M. clivosa,* outcrops on the eastern side.

Ragged and Sand keys, the next group to the south, were not examined, but according to the observations of Prof. Louis Agassiz they are "formed by coral boulders."

Elliott's Key.—The western side of the southern end of this key was examined just north of the entrance to Cæsars Creek from the lower end of Biscayne Bay. The maximum elevation of the surface at that place is estimated to be 5 or 6 feet above sea-level. The surface is formed by coral-reef rock with a very thin coating of soil. The corals observed were *Dichocœnia stokesi, Orbicella annularis, Mœandra labyrinthiformis,* and *Agaricia agaricites.*

Meigs Key, in Cæsars Creek, between Elliott's and Old Rhodes keys, is composed of coral-reef rock, elevated on its northern end about 4 feet.

Old Rhodes Key.—Dr. Mayer visited this key and furnishes the following note: He landed on the Hawk Channel side near the middle of the key, and went about 100 feet inland, where he collected lithologic specimens of coral-reef rock. He states that the surface is exactly the same as that of Elliott's Key; it is rough, with numerous potholes, calcareous mud, and elevated reef corals. He collected specimens of *Orbicella annularis* and *Mœandra viridis.*

On a previous trip along the Florida East Coast Railway I had an opportunity to examine railway cuttings from Key Largo to Knights Key, inclusive. There are numerous exposures of elevated coral-reef rock along the line of the railway. Mr. Samuel Sanford, who is preparing a report for the U. S. Geological Survey on this portion of Florida, will present his observations in detail.

Pigeon Key, off the lower end of Key Largo, in the Inner Passage, has a surface composed of calcareous silt, with no reef corals exposed.

Lignum Vitæ Key, north of the upper end of Lower Metacumbe, has a surface composed of calcareous marl or mud.

Bahia Honda Key.—No coral reef was observed exposed on the surface of this key, the superficial material being loose calcareous sands. Dr. Mayer, however, had observed on a previous occasion, remnants of an old coral reef.

Big Pine Key.—The most westerly observed elevated coral reef rock was at the southeastern extremity of this key. The reef rock occurs at water-level, and extends beneath the water. *Orbicella annularis, Favia fragum,* and *Mœandra viridis* were observed. As wash on the shore, probably from the reef, specimens of *Dichocœnia stokesi, Manicinia gyrosa,* and *Mœandra labyrinthiformis* were obtained.

As is well known, west of Bahia Honda the trend of the main keys is not parallel to the Florida coast, but transverse to it, running from northwest to southeast. The following keys, excepting the southeastern corner of Big Pine, are composed of oölitic rock: No Name Key, Porpoise Key, Big Pine Key, excepting the southeastern corner; Ramrod Key, Summerland Keys, Knock 'Em Down Keys, Torch Key, Sawyer Key, and Key West Island. No coral bowlders were seen on Key West. Prof. Louis Agassiz, however, reports that their lower strata consist of coral bowlders and coral breccia, as was ascertained during the excavation preparatory to the foundation of the fort of Key West. None of the keys between Key West and the Tortugas were examined.

Loggerhead, Bird, and Garden keys of the Tortugas consist principally of comminuted shells and corals, which are sometimes considerably indurated.

The Florida keys, in the main line, between the point of land bounding the eastern side of the Bay of Biscayne to Key West, present three different types. First, the sand keys to the north, which comprise Virginia Key and Key Biscayne; second, the keys composed primarily of elevated coral-reef rock extending from Soldiers Key to the southern end of Big Pine Key; third, west of Bahia Honda the keys are composed mostly of an oölitic limestone. The Tortugas are lithologically different from any of the types just recorded.

Within the main line of elevated coral-reef keys and transverse to them are shoals which in some instances are built to the surface of the water, and form mangrove keys. It appears that these shoals are formed in the following way: Between the separate keys of the main line are channels out and in which the ocean currents flow. The currents in these regions are very strong. Behind any given key is a region of slack-water, and therefore one of deposition. Shoals consequently are built up behind the keys, and are elongated in a direction transverse to their axes. In the course of time these shoals approached sufficiently near to the surface of the water for floating young mangroves to catch on the bottom. The mangroves grow rapidly, establishing a mangrove key, and then become a constructive agent, ultimately bringing the land surface of the key above the surface of the water. This appears to have taken place in both Virginia and Lignum Vitæ keys.

The mode of origin of the Florida oölite has been the subject of considerable discussion and divergence of opinion. My opinion is that it has been formed as a water-laid deposit, probably behind a seaward barrier. The reasons for this opinion are that numerous marine fossils are found in the oölitic material, the two valves of bivalve mollusks are frequently in place, showing no damage by attrition, and fossil corals which exhibit no indications of having been rolled or waterworn were found. The marine fossils found in the oölite had evidently lived in the water during the formation of the oölite.

On the surface of Big Pine Key original mud-cracks, formed by desiccation, were observed and photographed.

I also made a short expedition to Picquet Rocks, Gun and Cat keys of the Bahamas, in order to compare the geological formations of southern Florida with those of the Bahamas.

BOTTOM DEPOSITS.

The material of the bottom of the sounds within the main lines of the keys and between the keys and the coral reefs was made the subject of as detailed investigation as circumstances permitted. Series of samples were procured, particularly on the inside of the main line of the keys from Miami to Key West. These samples have not as yet been fully studied in the laboratory, but it may be noted that siliceous sand grains formed a certain proportion of the bottom material as far down as Barnes Sound, and small quantities were found after entering Florida Bay proper as far down as the north side, 3 miles offshore, of Long Key. It may also be remarked that the Miami oölite extends beneath the northeastern portion of Biscayne Bay.

MADREPORARIA OF SOUTHERN FLORIDA.

I have undertaken the study of the Madreporaria of the Florida region particularly for the purpose of obtaining information on the variation of the Madreporaria, the physical and chemical factors influencing variation, and the physical and chemical determinants limiting the distribution of corals.

General survey of the coral fields.—I began this work by undertaking a general survey of the Florida reef region, and attempting to determine the distribution of the various forms with reference to a number of factors. In order to obtain the necessary information for these studies, I designed the following field label, using a Library Bureau card, so that the data obtained could subsequently be classified according to various factors:

CARNEGIE INSTITUTION.

Investigation of the Madreporaria of the Florida Keys.

Locality No.....

Key.....; side.....; distance from shore.....

Bottom: material.....; topography.....

Water: depth.....; temperature.....; tides.....

.....relative purity.....

Currents: direction.....; rate.....

Winds..... Breakers.....

Date..... ..... Collector..... .....

Associated fauna.....

Additional remarks: .....

Specific collections were made at several places and all possible information obtained regarding the conditions under which they lived. Turtle Reef, Carysfort Reef, and the reefs in the vicinity of the Tortugas were examined with as much thoroughness as circumstances permitted, and collections were made at several places within the main line of keys. This material was shipped to Washington, and will be studied in detail in the laboratory. It

was ascertained that numerous species of corals were sharply limited in their distribution, but no attempt will be made to formulate the determining factors until the collections have been carefully studied.

A considerable amount of experimental work was initiated on the Tortugas in the hope of obtaining information on several subjects.

Rate of growth.—As many corals grow on the concrete piers of the Government dock off Garden Key, an excellent opportunity is afforded for observations on the rate of growth of the species there represented. Measurements were made on the following species, and they will be observed from year to year: *Oculina* sp., *Eusmilia knorri, Manicina gyrosa, Mœandra clivosa, Agaricia agaricites, Porites porites* var.

Fort Jefferson is surrounded by a moat to which the sea has access. The water in this moat is usually sluggish, and although during periods of heavy rain its degree of salinity is less than that of the ocean, several species of corals grow in it. Individuals of these were selected for growth observations.

Transplanting specimens.—Specimens of *Mœandra clivosa,* which habitually grow on the outer side of the piers of the Government dock, where the light is strong, were removed from the outer piers and attached to the inner piers so as to observe the effect of the change in environment.

Specimens of *Oculina* sp., *Eusmilia knorri, Orbicella annularis, Favia fragum, Mœandra labyrinthiformis, M. areolata, M. clivosa, Porites porites* var., were taken from the outside and planted in the moat. They were measured, and will be kept under observation.

Rearing corals from the young.—Specimens of the following species were found growing on the reefs off the western side of Loggerhead Key, opposite the light-house: *Orbicella annularis, Favia fragum, Mœandra clivosa, Agaricia agaricites,* and *Porites astreoides.* Live specimens of *Orbicella annularis, Favia fragum, Agaricia agaricites,* and *Porites astreoides* were brought into the laboratory and kept under observation. Specimens of *Favia fragum* and *Porites astreoides* were extruding planulæ. These were allowed to settle on pieces of glass placed in the vessel or on the bottoms of the vessels themselves.

Porites astreoides.—Planulæ were extruded the night of May 3, 1908, attached probably the night of May 10. On May 27, 1908, the calice, according to information furnished by Dr. Mayer, measured 2.5 mm. in diameter. This individual subsequently died.

Favia fragum.—Planulæ were extruded on the night of May 6, 1908. Dr. Mayer, subsequent to my departure from the Tortugas, continued observations on the planulæ and the attached young.

1 attached May 11, 1908.
0 attached May 12 and 13, 1908.
40 attached May 14, 1908.
12 attached May 15–17, 1908.
2 attached May 18, 1908.

On July 22, there were 6 young corals in the dish. Four of these were single calices and 2 were double, due to the fusion of 4 originally separate polyps. The dimensions of the individuals were as follows:

(*a*) Single calice 5 mm. in diameter.
(*b*) Single calice 4 mm. in diameter.
(*c*) Single calice 4.5 x 4 mm.
(*d*) Single calice 4.5 mm. in diameter.
(*e* + *f*) Double calices 5.5 x 4.5 mm.
(*g*) Double calices 4 x 3.5 mm.

All of the young of the *Favia fragum* were attached to the bottom of the dish, which has been suspended in a wire cage from a floating live-car and anchored off Loggerhead Key.

This seems to be the first attempt to rear corals from the young. As it is a new project, the methods of experimentation had to be devised, and it appears that they have been discovered. The initial experiments indicate success in the undertaking. In subsequent years attempts will be made to obtain the young of all the species represented in the Tortugas region, and to plant attached young of the same species under different environments, so as to observe the influence of change of environment on variation.

One of the subjects that has attracted attention of the students of Madreporaria is the means by which distribution is effected. As is well known most corals thrive best in regions of considerable current. One planula of *Porites astreoides* was free for about 7 days. The duration of the free-swimming larval stage in *Favia fragum* ranged between 5 and 12 days. These data show that currents are probably able to effect wide distribution. The rate of the Gulf Stream is estimated at approximately 3 miles per hour, which is 72 miles per day. The maximum observed duration of the free larval stage of *Favia fragum* was 12 days. This would indicate the possibility of a larva of *Favia fragum* drifting over 800 miles.

A Collection of Hydroids Made at the Tortugas, during May, June, and July, 1908, by W. Seward Wallace.

The greater portion of my time while at the Laboratory was devoted to collecting and, as far as time permitted, studying and sketching, the hydroids of the region. In general it can be said that there is a fairly abundant hydroid fauna, specially of the smaller and more delicate forms of the Plumularidæ and Campanularidæ; and this is not remarkable, considering the large number of medusæ found to occur here.

Collecting was carried on in the usual way, by dredging, raking bottom, scraping and examining the algæ, sponges, gorgonians, docks, boats, live-cars, and submerged objects generally. It was kept in mind that the hydroids are found at all depths, in all sorts of situations, and that their colonies are very often disguised by parasitic growths of other hydroids, of algæ and particularly the *Suctorians,* such as *Podopheya,* hiding the true character of the growth.

Speaking broadly, about 50 or more species were collected, most of them common to the Bahama-Florida region, but some are of considerable interest because of their rarity. Several of the new species described by Prof. C. C. Nutting in his Hydroids of America were identified, among them *Aglaophenia contorta, Monotheca margaretta, Plumularia mermis, Plumularia alternata, Sertularia versluysii* (new name), and others. In the latter case, if the identification is actual, I shall be able to add the description of the gonosome. As considerable of the material collected was not examined thoroughly, doubtless the estimate of 50 species is a low one.

Plans to construct a table of depths and habitat may be frustrated by the widely scattered situations in which certain hydroids are found, *Halopteris carinata,* for example, being found in all dredging depths from 3 or 4 fathoms up to 18 fathoms, while *Halecium sessile* is found everywhere in freely

flowing tide-water. But undoubtedly the thecate forms are as abundant as the athecate ones, Campanularidæ and Halecidæ being as abundant as Plumularidæ; while the gymnoblastic hydroid groups are represented by but a few species. No members of the genus *Tubularia* were found, nor of the Corynidæ except *Zanclea.*

The following tentative list of identified hydroids can be given:

GYMNOBLASTÆ:

Zanclea gemmosa (McCrady), gonosome and medusa.
Pennaria; one species (probably not *gibbosa* Agassiz).
Eudendrium carneum Clarke, male, female, and gonosome.
"Eudendrium" hargettii Congdon (discovered 1906, Bermuda), male, female, and gonosome.

CAMPANULARIDÆ:

Clytia bicophora, gonosome, medusa. *C. noliformis,* gonosome.
Obelia dichotoma, gonosome, medusa. *O. (commissuralis?),* gonosome, medusa. Other Obelidæ not yet identified.
Campanularia flexuosa (Hincks), female capsules. *C. calceolifera,* medusa. *C. minuta. C. amphora* Agassiz, gonosome. *C. insignis* Allman, female capsules, hydranths, dredged. *C. (edwardsii?)* Nutting.
Halecium sessile. C. (articulosum ?). C. markii Congdon, female (?), and male capsules, hydranths. Other Halecidæ, not identified.
Thyroscyphus ramosus Allman, dredged.

PLUMULARIDÆ:

Statoplean:
Aglaophenia minuta Allman. *A. lophocarpa* Allman. *A. perpusilla (?). A. contorta* Nutting. *A. mammillata. A. rhynchocarpa.*
Lytocarpus philippinnus.
Eleutheroplean:
Plumularia florida (?). E. cetacea Ellis. *E. inermis. E. alternata* Nutting. Others of this genus not identified.
Monotheca margaretta Nutting.
Monostaechas (quadrideus ?) or some related species.
Halopetris carinata. And others.

SERTULARIDÆ:

Sertularia (rathbuni). S. tumida. S. versluysii, gonosome. Several of this genus.
Sertularella distans.
Pasythea quadredentata. Variety with 3 to 4 pairs thecal to each node.
Diphasia digitalis.

While I do not consider this list either as complete or as certain, until further study of the collection, it includes a variety of genera and species divided among four great groups of hydroids, such as to form a basis for future study of Tortugas hydrozoa.

Zanclea gemmosa, heretofore recorded from Charleston, and from Woods Hole, Massachusetts, is not the *Zanclea* found previously at Tortugas by Dr. Mayer, and named *Z. gemmosa.* That hydroid has the tentacles arranged in whorls, while the gonophores bud from below the proximal whorl. In the specimens I found, the tentacles were truly "scattered," neither spiral nor whorled arrangement being observed in hundreds of specimens examined. The gonosome arises proximally, but often above 3, 4, or more tentacles, and the lack of the heavy perisarc is evident at the base of the hydranths.

The medusæ in the two forms, *Zanclea implexa* and *Z. gemmosa,* seem to be identical, and agree with the Woods Hole and English form.

A special comparative study of the *Pennaria* found at Loggerhead Key and Garden Key and of the European *Pennaria cavolini* was made at the suggestion of Dr. Mayer, who placed in my hands his material from Naples gathered fresh in 1908, and preserved beautifully expanded in alcohol.

Space forbids my detailing the results of this study; but the result was to prove that *Pennaria cavolini* is a species quite distinct from the Tortugas form, the chief difference lying in the crenulations on the ultimate hydranth ramuli. In *P. cavolini* those on the lateral hydranths are wholly annulated, the ramulus usually being shorter than the hydranth itself, and becoming gradually smaller from base to summit. In the Tortugas hydroid, on the contrary, the ramuli of lateral hydranths are only annulated proximally, are usually longer than the hydranth, and increase in size, or swell, from the proximal to the distal end. These characters also seem to separate it from *P. tiarella,* and do not agree with Agassiz's "Gulf of Florida" form, *P. gibbosa.* A more complete comparison of all four species will be made as soon as material can be obtained.

We met with no storm during 1908, which has been the most uneventful year in the history of the Laboratory. The yachts were safely laid up in the Miami River, Florida, on July 29. All of the investigators enjoyed good health, and all returned to the north with vigor improved by their life in the open air of the tropics.

The action of President Roosevelt in setting aside the Tortugas as a National game preserve enabled us to safeguard all of the birds upon Loggerhead Key, and as a result we now have a small but well-established colony of the rare least tern nesting upon the island.

To our kind friend Commodore William H. Beehler, U. S. N., commandant of the naval station at Key West, we are indebted for generous aid rendered to us upon all possible occasions.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

LEWIS BOSS, DIRECTOR.

This report covers the operations of this Department to August 15, 1908.

Our work has continued on much the same lines as in the previous year, except that the section of observations has again become the more important feature. From October 7, 1907, to August 15, 1908, a period of 10 months, 10,421 meridian observations have been made with the Olcott meridian-circle. These observations were made mostly by Chief Assistant Arthur J. Roy and Assistant William B. Varnum. They are of a fundamental character and a large proportion of them are upon the standard stars. The objects of observation are distributed over the entire sky available at Albany for practical observation from 83° north zenith-distance to 40° of south declination. They furnish the points for comparison with like observations to be made upon the same stars from the observatory to be established in the Southern Hemisphere.

Much progress has been made during the past year in preparation for the establishment of an observatory in the Southern Hemisphere. It has been virtually decided to locate this at San Luis, in the Argentine Republic. San Luis is a town of about 10,000 inhabitants, situated on the Trans-Andean Railroad, about 500 miles west of Buenos Aires, and approximately 2,500 feet above sea-level. Its geographical coordinates are about 66.3° longitude west from Greenwich, and 33.3° south latitude. The climate is reported to be dry and healthful, and to offer a very unusual amount of clear sky.

The U. S. Department of State has proved especially helpful in bringing the proposed expedition properly to the attention of the Argentine Government. Mr. Root has evinced a cordial and personal interest in this matter, entitling him to my most sincere thanks. The Argentine minister to the United States, Señor Don Epifanio Portela, has been most obliging in securing attentions from his government, designed to facilitate the choice of site and the safe entry of our material and apparatus. Other representatives of the Argentine Government have also shown particular interest in matters concerning the establishment of the new observatory.

Arrangements have been completed to dispatch a preliminary expedition to the Argentine Republic for the purpose of choosing a site for the new observatory; to provide for it the necessary observing rooms, offices, and quarters for the staff; and in general to prepare it for the reception of its staff.

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* Address: Dudley Observatory, Albany, New York. Grant No. 479. $20,000 for study of motion and structure of the stellar system of the northern and southern hemispheres. (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.)

The Director of this Department, accompanied by Prof. R. H. Tucker and Mr. William B. Varnum, sailed on this service August 20, from Brooklyn, on the steamship *Velasquez* for Buenos Aires. Materials for the most difficult parts of the constructions required were taken along with the party, together with a variety of apparatus.

The Director expects to return to New York about November 4, after initiating the necessary arrangements for location and construction of the observatory, leaving this work to be carried out by Professor Tucker, assisted by Mr. Varnum.

It is designed to send the second party to Argentina December 19, or at some later date when it shall have been ascertained that the new observatory is sufficiently ready for occupancy. This second party will also be in charge of the Director of the Department, who will personally take it to its destination. The membership of this second party is at present arranged as follows: Chief assistant, Mr. Arthur J. Roy; assistants, Sanford and Zimmer; recorders, Fair, Gibble, and Delavan.

With this staff will also be taken the Olcott meridian-circle belonging to the Dudley observatory, together with its extensive subsidiary apparatus, clock, chronographs, etc., a photometer, and other needful apparatus. On arrival at the new observatory the meridian-circle is to be installed at once upon the massive concrete piers prepared for its reception, duly adjusted, and tested. The work of observation is to begin at once, and it is estimated that the program of observation, which has been carefully studied and arranged, can be completed within three or four years. The instrument will then be returned to Albany for the purpose of completing the corresponding observations to be made there.

Arrangements have been perfected for the prompt computations of the results derivable from the observations, as nearly up to date as the proper derivation of constants will permit. One of these computations will be carried on at San Luis as a duplication of the more elaborate one to be executed at Albany.

The observatory will be left in charge of Prof. Richard H. Tucker, who has leave of absence from the Lick Observatory during the time required for the work. Professor Tucker was an assistant at the Dudley Observatory 25 years ago, was chief assistant for many years at the national observatory at Córdoba, Argentina, and after that became an assistant at the Lick Observatory, and subsequently chief assistant there, where during the last 10 years he has produced many notable works in meridian-observation. Messrs. Roy and Varnum are also experienced observers with our meridian-circle. So that the probabilities seem to be in favor of a speedy and precise execution of the plans.

Since the date of my last report the Preliminary General Catalogue of 6,188 stars has been completed, and the printer's copy has recently been sent to the Carnegie Institution. The completion of this work has been delayed through a variety of causes connected with the large scheme of observations and reductions carried on throughout the year, together with other extensive pieces of computation growing out of results derivable from the new Catalogue, and also with the preparation of the program of observation for the Southern Observatory.

Among these a careful discussion of the solar motion is a prominent feature. This has been completed so far as the determination of the solar apex is concerned. The definitive result of this, for 1875, so far as the present material is concerned, is:

R. A., 270° 31′; Decl., +34° 17′

The results in detail for four pairs of zones, symmetrical with the equator, are:

	A	D
0 to ±10°	270°.0	+34°.5
±10 to ±30	270 .8	+31 .0
±30 to ±50	273 .8	+38 .3
±50 to ±90	272 .8	+30 .0

Restricting the computations to stars of the sixth magnitude and brighter, we have

A=269° 52′ D=+34° 39′

For stars having motions larger than 20″ per century the result is

A=272° 29′ D=+34° 28′

These results of the partial areas seem to be so accordant that it is difficult to suspect that there are anomalous deviations from the law of random motions in various parts of the sky or at different distances from the sun.

Results derived from the material distributed in zones parallel with the Galaxy are equally accordant with these, but show that the mean distances of the stars near the plane of the Galaxy are greater than those of the stars near the poles. But in this part of the discussion peculiarities of motion have been developed that require further study.

The material of observation is now being prepared for a further discussion by methods other than those employed in obtaining the results presented in the foregoing, and by methods calculated to throw light on the relation of the stellar-motions to the system of the Galaxy. Of this part of the work it would be premature to speak at present.

During the discussion for the solar motion, of which the main results are presented in the foregoing, a special research was made that led to the following results, stated in summary:

(1) Newcomb's centennial luni-solar precession requires an apparent correction of +0.53″, making our result about half-way between those of Struve and Newcomb.
(2) Newcomb's centennial planetary precession seems to require a correction of only +0.06″.
(3) Newcomb's centennial motion of the equinox, N, now generally adopted, seems to require a correction of +0.79″.

All of these quantities appear to be established within small limits of probable error, though the last seems to be unexpectedly large.

Our new Catalogue contains 41 stars (two doubtfully) in the constellation Taurus, which seem to belong to a cluster, of which the individual members are moving with uniform direction and velocity in space. The facts of the case seem to be very accurately indicated through the precision of the motions contained in our General Catalogue. There are many stars not contained in our Catalogue that also belong to this cluster, which is scattered over an area of sky nearly 15° in diameter, with pronounced condensation in its central parts. The motions of the stars in this cluster are found to be accurately convergent upon a point, of which the right-ascension for 1875 is $6^h\ 7^m$ and declination +6° 56′. The inclination to the plane of the Galaxy of these motions in space is only —5°. Through the motions in the line of sight of three of these stars measured by Professor Küstner of Bonn, the velocity in space, with relation to the sun, of these motions is found to be about 46 kilometers per second (28 miles). The cluster passed its nearest point to the sun about 800,000 years ago, in recent geological times. Its distance from the sun at that time was approximately half its present distance. Its present distance is indicated by a parallax of the center of the cluster of about 0.026″, a quantity too small to be measured with relative accuracy by direct measurement; but observers with powerful spectroscopes will undoubtedly be able to verify the hypothesis which has led to the foregoing conclusions (uniform velocity and directions of motion), so that we are likely to be ultimately assured of the reality of this unique phenomenon.

The new Catalogue contains evidence in regard to several other groups of stars, smaller in number and extent, that exhibit phenomena of the nature that characterizes the Taurus cluster, except that, owing to the small extent of these clusters, it does not seem to be likely that the radiant or convergent of any of these can be established at present.

A large amount of work has also been accomplished in relation to the larger General Catalogue, designed to embrace about 25,000 stars, and in the interests of which the new Southern Observatory is about to be established; but as these consist mainly of masses of preliminary computation, the detailed mention of them does not appear to be called for in this place.

I can not close this brief report without mentioning my appreciation of the zeal, loyalty, and efficiency which has characterized the labors of the staff throughout the year. During most of the time 10 persons have been em-

ployed. The most responsible part of the work has been done by Mr. Arthur J. Roy, chief assistant, and by Mr. William B. Varnum, second assistant. The efficiency of these two (and especially of Mr. Roy) in the work of fundamental observation has been worthy of all praise.

Recently 4 young men have been added to the staff in order to secure needed training for their intended work at the Southern Observatory.

SUPPLEMENTARY REPORT SUBMITTED NOVEMBER 30, 1908.

Since the date of the foregoing report, rendered in August, 1908, I have visited the Argentine Republic and have made arrangements for the establishment of a temporary observatory, at San Luis, in approximate latitude $-33^\circ\ 18'$, longitude $4^h\ 25^m\ 25^s$ West of Greenwich.

Accompanied by Prof. Richard H. Tucker, of the Lick Observatory, who is in charge of the new observatory, and Mr. W. B. Varnum, for many years an assistant at the Dudley Observatory, I left New York on the steamship *Velasquez* August 20, and arrived in Buenos Aires September 13. We had taken with us the necessary ironwork for the floor, and the prepared framework of a wooden roof, for the transit-circle house, with shutters and necessary devices for operating the same; molds for the concrete piers designed for the support of the transit-circle; a chronometer, barometer, and a variety of small apparatus and supplies intended for the use of the new observatory.

The expedition had been provided with a favorable introduction to the Argentine authorities by Hon. Elihu Root, Secretary of State, who has evinced a warm personal interest in our enterprise. Aided by this and by the valuable influence and interest of Hon. Walter G. Davis, Director of the *Oficina Meteorologica* of Argentina, and of Dr. L. S. Rowe, of the University of Pennsylvania and temporarily resident in Buenos Aires as a Research Associate of the Institution, the friendly disposition of the proper officers of the Argentine Government was promptly enlisted in our behalf. I was received in the most friendly manner by the Ministers: De la Plata, of Foreign Affairs; Naón, of Justice and Public Instruction; Ezcurres, of Agriculture, and others. The Argentine Department of Agriculture, at its own expense, provided us with a large freight car for the prompt transportation of our material to San Luis, where it arrived intact; and also with passenger tickets and accommodations over the Pacific Railroad. The Department of Justice and Public Instruction offered us a site on national property belonging to the *Escuela Regional* in San Luis, previously examined and recommended by Mr. Davis, and this site subsequently proved to be most admirable for the purpose required. In the kindest manner Mr. Davis acted practically as our agent in Buenos Aires, executing a variety of commissions in our behalf.

Upon our arrival in San Luis on the morning of September 20 we were met at the station by a party of officials of the Provincial Government of San Luis, including Señor Don José Gazari, acting Governor, Señor Don Modesto Quiroga, Secretary of State and Finance, Señor Don José Romanella, Mayor of San Luis, and others, together with many prominent citizens of San Luis.

In order that we might be quartered near the possible site of our future operations it had been arranged that we should enjoy the hospitality of the *Escuela Regional,* which is under the direction of Dr. C. L. Newton. This proved to be a very convenient arrangement. The site offered by the National Government was inspected on the day of our arrival and definitely accepted on the following day. It is located on the domain of the *Escuela Regional,* as already stated, and its altitude is approximately 2,500 feet above sea-level. It is about one kilometer from the principal plaza of the city, but in a position sufficiently isolated from buildings. It is also within convenient reach of the water-supply of the city. This site and its immediate surroundings constitute a wide-spreading plain extending to the base of the San Luis Mountains about 3 kilometers to the northeast. These mountains add a most attractive feature to the landscape. Owing to the extremely dry climate of the province of San Luis, the terrain supports only a scanty covering of vegetation, except in places where resort is had to irrigation. The plot upon which the new observatory is to be located is under irrigation and covered with a luxuriant growth of alfalfa. The effect of this is greatly to protect the soil from undue variations of radiation—a feature that is naturally of great importance in astronomical operations. The subsoil here offers very great advantages for the construction of piers for the instruments. Underneath the covering of rich vegetable mold is a stratum of sandy loam, of from 3 to 5 feet in thickness. Underneath this again is a layer of gravel of nearly equal thickness, and below that a dry, hardened clay. Nothing better as a foundation for the transit-circle piers could be imagined.

Within less than a week after our arrival the true meridian was established by observation with a small theodolite, the foundations of the building were staked out, contracts for building material were made and the selected site of the observatory, covered with piles of brick, broken stone, sand, and other material, presented a busy scene. Plans for the observing room, and of the building designed for offices and quarters for the staff of observers, had been prepared previous to our departure from Albany. The transit-circle house is to be constructed of brick with a wooden roof, and contains a single room 22 by 23 feet. The office building of brick with galvanized-iron roof is to be approximately 80 by 60 feet in exterior dimensions, with a large interior court, or *patio*, in the usual Spanish-American fashion. This building is to be of one story and of the simplest construction. Detailed description of the

arrangement of buildings and instruments may well be deferred until a future occasion. On October 5, in the presence of a small party of officials and friends, the first stone of the foundation was laid with simple ceremonies.

During the whole of my stay in San Luis the authorities of the city and province and the leading citizens generally evinced the most cordial interest in our plans. In particular, Señor Don Modesto Quiroga, provincial Minister of State and of Finance, was unremitting in his attentions and assistance. Dr. C. L. Newton, Director of the *Escuela Regional,* was constantly engaged in the performance of valuable services in our behalf in addition to the hospitality which he dispensed in behalf of the National Government. Señor Don José Romanella, Mayor of San Luis, facilitated our operations in valuable ways. In a word, every one whom I met seemed to feel a keen interest in the success of our enterprise and anxious to assist it in any way that offered an opportunity.

On October 7 I arrived in Buenos Aires on my return trip, and on October 10 embarked on the steamship *Velasquez,* bound for New York. On the sixth day out, at a point about 100 miles south of Rio de Janeiro, this ship, on a night of inky darkness with fog and rain, ran ashore at full speed upon the rocky coast of San Sebastian Island. The ship and its cargo became a total loss; but after some dangers and hardships all the passengers and crew, together with nearly all their baggage, were saved and returned to Santos, Brazil, from which port I reembarked on the steamship *Titian,* which arrived in New York November 11.

Owing to the delay in my return to New York the time of my second trip to Argentina, with the remainder of the observing staff for the Observatory of San Luis and with the instruments, has been provisionally postponed until the sailing of the steamship *Verdi,* January 20, 1909, from New York. It is hoped that the new observatory will be ready for the reception of instruments and observers at that time.

MOUNT WILSON SOLAR OBSERVATORY.*

GEORGE E. HALE, DIRECTOR.

The continuation and extension of the researches described in my last annual report have led to the following results:

(1) The comparative study of the spectra of the limb and center of the sun favors the conclusion that the relative displacements of the lines near the limb (after eliminating the Doppler effect) are due to pressure. Further laboratory work is required before a final decision can be reached.

(2) The angular velocity of the solar rotation, as determined from the motions of the calcium (H_2) flocculi on spectroheliograph plates, decreases from the equator toward the poles. The mean velocity at any latitude is very nearly the same as that of the sun-spots.

(3) The angular velocity of the solar rotation, as determined from the motion in the line of sight of the hydrogen represented by dark lines in the solar spectrum, is more rapid at the equator than the angular velocity of the spots and calcium (H_2) flocculi, and decreases less rapidly toward the poles.

(4) The hydrogen ($H\delta$) flocculi, as measured on spectroheliograph plates, move at the equator with about the same angular velocity as the calcium (H_2) flocculi, and show no evidence of retardation toward the poles. This result was obtained before the discovery of solar vortices, and must be tested by measurements of the motions of $H\alpha$ flocculi lying outside of the vortices.

(5) Investigations with an electric furnace have shown that such changes of relative intensity as are exhibited by the lines of iron, titanium, and other substances in sun-spots are produced by lowering the temperature of the furnace. This confirms our conclusion that the temperature of these vapors in sun-spots is lower than in the reversing layer outside of spots.

(6) The flutings of calcium hydride, as observed in another form of electric furnace, have been identified with flutings in our photographs of sun-spot spectra. This is a further confirmation of the above conclusion.

(7) Through the use of the $H\alpha$ line of hydrogen, it has become possible to photograph a hitherto unexplored region of the solar atmosphere. The photographs show that sun-spots are surrounded, and probably produced, by extensive vortices, which draw the hydrogen, and doubtless other high-level gases, into the spots at great velocity.

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* Address: Observatory Office, Pasadena, California. Grant No. 480. $85,000 for construction, investigations, and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, and 6.)

(8) The components of double lines photographed in the spectra of sun-spots with the 30-foot spectrograph of the tower telescope have been found to be circularly polarized in opposite directions. This and much other evidence indicates that sun-spots probably contain a strong magnetic field. By means of spectrographic observations the areas, strengths, and polarities of these fields can be measured, thus permitting a magnetic survey of the entire visible hemisphere of the sun to be made.

In addition to these investigations, much work of research described in other parts of this report has been done, and the work of construction has advanced very satisfactorily. A spectroscopic laboratory in Pasadena, equipped for investigations requiring very high temperatures and pressures, was completed and occupied in March. The steel building and dome on Mount Wilson for the 60-inch reflector are nearly finished, and the telescope mounting is being erected on its pier.

STAFF.

Mr. W. S. Adams has continued his work as superintendent of the computing division, and Mr. G. W. Ritchey has had charge of construction, both in Pasadena and on Mount Wilson. Dr. Arthur S. King, formerly of the University of California, has been appointed superintendent of the physical laboratory, and commenced work on January 1. Dr. Charles E. St. John, formerly Professor of Physics and Dean of Oberlin College, joined our staff in May. Mr. Ferdinand Ellerman has continued his work with the Snow telescope. Since the completion of the Pasadena laboratory, Dr. Olmsted has carried on his spectroscopic work there. Miss Louise Ware, Miss Jennie B. Lasby, Miss Ruth E. Smith, and Miss Cora G. Burwell have continued their study of photographs in the computing division. Miss Lillian M. Wickham joined the staff of the computing division on February 1.

Prof. Ernest F. Nichols, Research Associate of the Carnegie Institution of Washington, has been engaged in an investigation of the absorption of the sun's atmosphere and in laboratory investigations on Mount Wilson during the summer of 1908. Dr. Walter M. Mitchell, director of the Haverford College Observatory, and Mr. H. C. Plummer, of the Oxford University Observatory, have also spent some time on Mount Wilson, for the purpose of becoming familiar with the investigations in progress.

The work of the Smithsonian Expedition, carried on by Mr. Abbot during the summers of 1905–06, was renewed on Mount Wilson in May and is still in progress. Mr. Abbot is assisted in this work by Mr. Louis B. Aldrich, of the University of Wisconsin. It is a satisfaction to state that arrangements have now been made by the Smithsonian Institution to construct a permanent station on the mountain, where studies of the solar constant and other investigations will be continued regularly in the future.

INVESTIGATIONS IN PROGRESS.

Direct Photography of the Sun.—Direct photographs of the sun have been made daily, as heretofore, with the Snow telescope.

Work with the Spectroheliograph.—The total number of photographs of the sun taken with the 5-foot spectroheliograph amounted, on September 30, to 5,196. In March, through the use of plates sensitized for the red by Wallace's process, it became possible to take photographs with the *Ha* line of hydrogen. These were found to differ in important respects from those obtained with *Hδ*. As it soon appeared that the *Ha* images gave a much more complete record of the hydrogen flocculi, mainly because of the great strength of this line in the upper chromosphere and prominences, where *Hδ* is weak, the former line was selected for the daily records, in place of *Hδ*. This change soon led to the discovery that sun-spots are surrounded by vortices, which occur in a region of the solar atmosphere higher than that recorded on *Hδ* plates. (See plate 6.) A full account of this work, illustrated with photographs of the vortices, may be found in No. 26 of the Contributions from the Mount Wilson Solar Observatory.

As the rapid changes in the vortices required that many photographs be made at short intervals, it became necessary to improve the performance of the Snow telescope and to modify the daily program of observations so as to include more *Ha* plates. As the result of experiment it was found that the reduction of the aperture of the cœlostat to 15 inches, while it only partially cured the rapid change of focal length caused by exposure of the mirrors to the sun, almost completely eliminated such evidences of astigmatism as had seriously injured earlier photographs. For this reason all *Ha* exposures are now made with the 15-inch aperture. The early morning observations are devoted exclusively to the photography of the disk with the *Ha* line. In the late afternoon additional *Ha* plates of the disk are taken, together with one prominence plate (using *Ha* in place of H_2, the line formerly employed), one H_1 disk and one H_2 disk.

The remarkable sharpness of the best *Ha* plates, and the evidence they invariably afford of the existence of definite vortices and currents in the solar atmosphere, have led to many important developments in our work with the spectroheliograph. It now becomes feasible to undertake a systematic examination of sun-spot theories, and to pursue many investigations hitherto out of reach.

Miss Ware's measurements of the motions of 1,680 points in the calcium (H_2) flocculi, made with the heliomicrometer on 51 negatives, taken with the 5-foot spectroheliograph during the period June 18 to September 22, 1906, have given the following results for the mean angular rotations (sidereal), corresponding to 5° zones (table 1). The means in the table combine the

results for corresponding latitudes in the northern and southern hemispheres, reduced from synodic to sidereal values.

Miss Ware has also measured the motions of 828 points in the hydrogen flocculi on 35 $H\delta$ plates (table 1). The difficulties of identification are much greater than in the case of the calcium flocculi, since the hydrogen flocculi change more rapidly in form. It is thus necessary to use plates separated by an interval of only about 12 hours, whereas the same calcium flocculus may frequently be measured on plates separated by an interval of two or three days.

TABLE 1.

Zone.	Calcium (H_2).		Hydrogen ($H\delta$).	
	No. of measures.	ξ	No. of measures.	ξ
° °		°		°
0± 5	232	14.5	129	14.3
± 5±10	262	14.3	105	14.1
±10±15	317	14.3	145	14.4
±15±20	326	14.2	120	14.4
±20±25	259	14.2	114	14.5
±25±30	153	14.0	95	14.6
±30±35	99	13.8	61	14.8
±35±40	26	14.0	43	14.8
±40±45	6	13.2	16	15.2

It will be seen that while the motions of the calcium flocculi clearly show a decrease in angular velocity toward the poles of about the same magnitude as in the case of sun-spots, the hydrogen flocculi do not appear to follow the same law.

This work was near completion when the first Ha photographs of the disk were obtained. The extensive whirls shown on these photographs indicate that the flocculi lying in the neighborhood of sun-spots, or within any region occupied by whirls, are unsuitable for the determination of the solar rotation. The $H\delta$ plates apparently represent the hydrogen in a lower region of the solar atmosphere, where the whirls are not clearly shown. Nevertheless, the motions of the $H\delta$ flocculi are probably affected by the whirls, which may account for many peculiarities encountered in the measurement of the plates. It accordingly becomes necessary to study the rotation at the Ha level, by means of flocculi which are well outside of the whirls.

A further extension of the spectroheliograph work will soon be possible, as the 30-foot spectroheliograph, constructed in our instrument-shop during the year, is now nearly ready for trial.

Spectra of Sun-spots.—Many photographs of spot spectra have been made during the year by Mr. Adams and myself. Most of these have been taken in the third order of the 30-foot spectrograph of the tower telescope and are greatly superior to the photographs made with the Snow telescope and 18-foot Littrow spectrograph. Double lines, which appear single in the previous photographs, are now clearly resolved, and a great number of additional faint lines, particularly those of flutings, are recorded. The preparation of a catalogue of the lines shown on the earlier plates was well advanced when the first of the new photographs was obtained. Their superiority has made it necessary to prepare a new catalogue, which will contain a much greater number of lines than the former one.

The hypothesis that the relative intensities of sun-spot lines are determined largely by a reduction in the temperature of the metallic vapors below that of the same vapors in the reversing layer is strongly supported by Dr. King's work with an electric furnace, described on another page of this report. Dr. Olmsted's detection of the red flutings of calcium hydride in spot spectra affords additional evidence in the same direction.

The discovery of the solar vortices suggested that the rapid revolution of electrically charged particles (assuming a preponderance of positive or negative ions, resulting from diffusion or other cause) should produce a magnetic field within sun-spots (Rowland effect). Photographs of spot spectra taken with the 30-foot spectrograph and the tower telescope showed a great number of close double lines, many of which had previously been seen visually by Young and Mitchell, who described them as "reversals." I accordingly examined the components of these lines and found their light to be circularly polarized in opposite directions. This is what would be observed if the vapors giving rise to these lines were seen along the lines of force of a strong magnetic field. Other spot lines, which are widened but not doubled, were found to be shifted in position when the nicol was rotated. Thus the widening may also be due to the effect of a magnetic field. If the laboratory work now in progress supports the solar observations, this discovery should have an important bearing on many questions of solar, terrestrial, and molecular physics.

Photographic Comparison of the Spectra of the Center and Limb of the Sun.—The completion of the tower telescope, and the much more powerful spectrographic apparatus available with this instrument, led to the transfer of the spectroscopic work on various parts of the sun's disk from the Snow telescope to the tower. The considerably greater dispersion available has proved to be of particular value in connection with Mr. Adams's study of the spectra of the center and limb of the sun, the quantities measured being so minute as to require the greatest linear scale which it is possible to obtain. In order to secure the two spectra simultaneously, and thus avoid possible errors arising from change of temperature or unequal illumination of the grating in the

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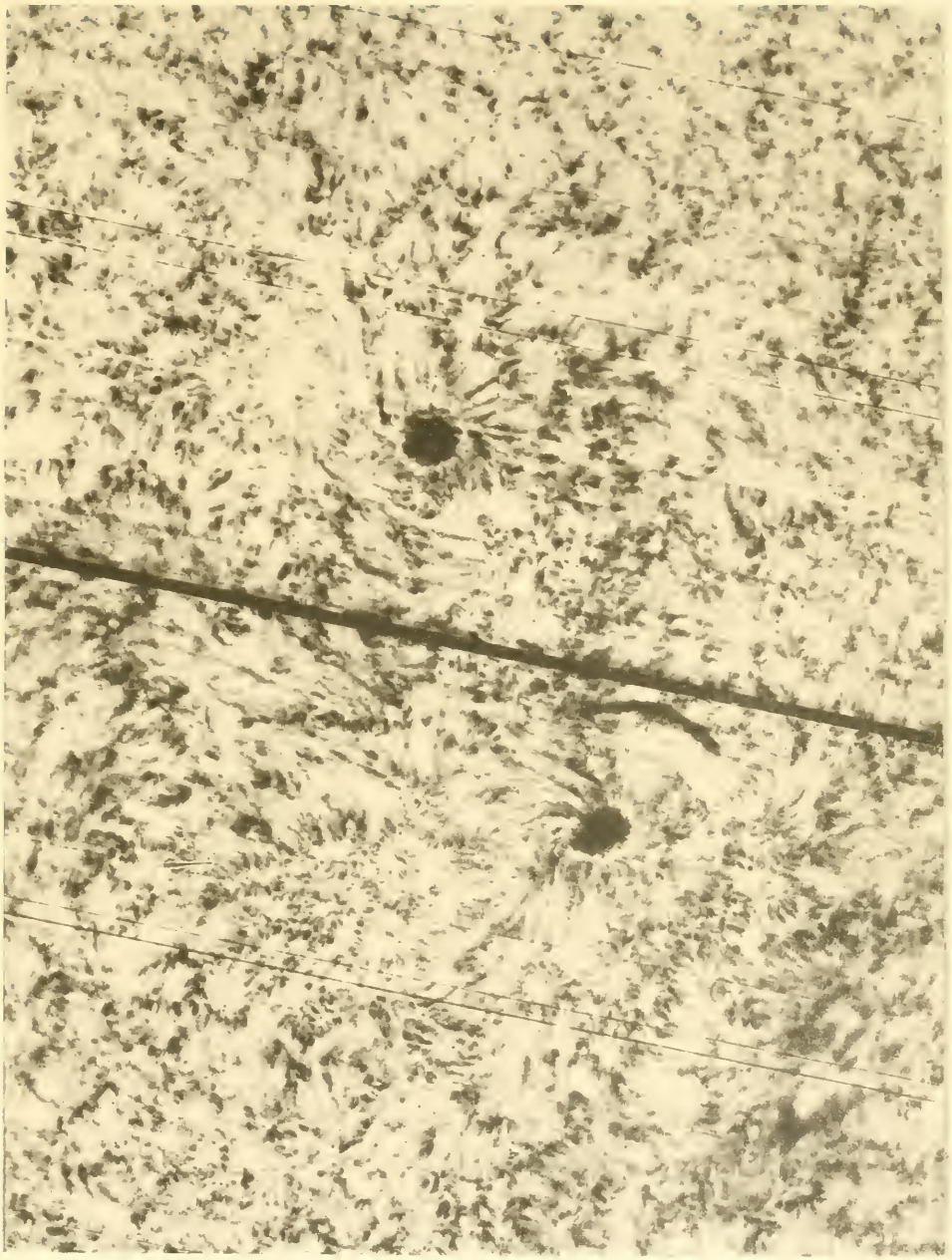

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The Sun, showing Sun-spot Vortices rotating in opposite directions, 1908, October 7, 7^h 02^m a. m., Pacific Standard Time, from a negative 6.73 inches (171 mm.) in diameter, made with the Snow telescope and 5-foot spectroheliograph, camera-slit 0.075 mm. (1.7 Ångströms) wide, set on the hydrogen line Hα.

COCKAYNE, BOSTON

two positions of the sun's image on the slit, a special attachment has been constructed for the purpose. Two small diagonal prisms throw light from the edge of the sun upon the slit, while the light from the center passes unobstructed on either side of the central prism. Photographs taken with this apparatus have proved extremely satisfactory and thoroughly reliable as regards the absolute displacements involved. At the present time negatives are being taken for the purpose of providing a photographic map of the spectra of these two portions of the sun's disk, and it is expected that this map will be completed some time during the winter.

In addition to the conclusions drawn from the measurement of the displacements referred to in the last report, the important result has been found that the spark or "enhanced" lines in the spectrum seem to show greater displacements at the limb of the sun than do the majority of the other lines. This has a vital bearing on the question of the level at which these lines originate in the sun's atmosphere. It will require, for satisfactory explanation, a series of laboratory investigations on the displacements of spark lines under pressure.

Spectrographic Investigation of the Solar Rotation.—Mr. Adams's photographic investigation of the rotation of the sun, by means of the displacements of the spectrum lines at the opposite limbs, has been continued throughout the year with the powerful spectrograph of the tower telescope. The advantages of this instrument over the 18-foot spectrograph of the Snow telescope, with which the investigation of 1906 to 1907 was carried on, are very considerable. In addition to the superior quality of the solar image, and greater freedom from astigmatism and change of focus, the larger linear scale furnished by the instrument, and the possibility of setting for different position angles, by rotation about a vertical axis, have proved of great value. The plates employed in the study of the rotation from lines in the violet part of the spectrum have all been taken in the third order of the grating. Plates including the region about *Ha* in the red part of the spectrum have been taken in the second order.

About 25 plates covering the same region of the spectrum that was employed in the investigation of last year have been measured and reduced. The degree of accuracy obtained seems to be appreciably higher than that secured with the plates from the 18-foot spectrograph. The comparison of the results of the two series of observations indicates very close agreement in the latitudes running from 0° to 45°. From 60° to the pole, however, the values obtained from the present series fall appreciably below those of last year, the difference amounting to about 0.04 km. at a maximum. It does not at present seem probable that this difference is to be ascribed to a real variation in the rotation of the sun, since it is not shared in by the zones of lower latitude, in which the activity of the sun, as indicated by the presence of spots

and flocculi, is much greater. A more probable explanation would seem to be that it is due to errors arising in the former series of observations, from astigmatism and other defects of the solar image. The values obtained from the present year's series of observations are now being collected and will be published within a short time.

One of the most important contributions furnished by the investigation of the rotation of the sun is Mr. Adams's discovery that the hydrogen gas producing the α line of hydrogen moves with a decidedly greater angular velocity than the general reversing layer, and seems to be subject to quite a different law from that of the ordinary equatorial acceleration. The first indications that a result of this kind was to be expected were furnished by the study of photographs of the spectra of the center and limb of the sun, and as soon as these became evident the investigation was continued with the regular rotation apparatus of the tower telescope. The results obtained from the earlier plates of the series are given in table 2:

TABLE 2.

ϕ	v	$v+v_1$.	ξ	Period.
°	*km.*	*km.*	°	*Days.*
—0.1	2.07	2.21	15.7	22.9
9.3	2.01	2.15	15.5	23.2
14.8	1.96	2.10	15.4	23.4
22.7	1.90	2.03	15.6	23.1
29.7	1.73	1.87	15.3	23.5
44.5	1.44	1.55	15.4	23.4
59.3	1.04	1.12	15.6	23.1
73.5	0.63	0.67	16.7	21.6

The inclusion of a larger number of results will probably indicate a slight decrease in the value of the angular velocity toward the pole of the sun, but the law will evidently be very different from that of the reversing layer. It also seems probable that the value of the angular velocity at the equator will be somewhat reduced when a larger series of observations is available.

Some recent work on the blue line of calcium at λ 4227 indicates that the rate of rotation given by this line differs from that of the general reversing layer. A series of photographs obtained especially for the study of this line is now being investigated.

Absorption and Scattering in the Solar Atmosphere.—Prof. E. F. Nichols, professor of physics in Columbia University and research associate of the Carnegie Institution of Washington, has just completed an important investigation on Mount Wilson. The object of the work is to determine the law of absorption and scattering of light in the solar atmosphere. An image of the sun, formed by the Snow telescope, falls upon a slit. The rays which

enter the slit are rendered parallel by a collimating mirror, pass through a large prism, and the spectrum thus formed is brought to a focus by a second mirror. A bolometer, kindly supplied by Mr. Abbot, is set at a certain wave-length. As the sun's image transits across the slit, the deflections of the galvanometer are recorded on a moving photographic plate. In this way photographed curves, corresponding to a number of different wave-lengths, give a measure of the solar radiation at points along a diameter parallel to the direction of the diurnal motion. Several refinements of the method, which are due to Professor Nichols, should lead to results of high precision. The observations have been completed and will be reduced as soon as possible.

PHYSICAL LABORATORY.

To meet the needs of experimental work, which require the use of electric currents much stronger than can be economically generated on Mount Wilson, the construction of a new physical laboratory, on land adjoining our Pasadena instrument-shop, was begun in the autumn of 1907. On January 1, 1908, the work had progressed as far as the completion of the exterior walls and roof and the excavation of the 30-foot pit in the middle of the floor. During January and February the interior arrangements were for the most part completed, including the cementing and drying of the pit, the laying of the cement floor with conduits for electric wires embedded in the cement, the construction of concrete piers for the apparatus, the installation of the electrical machinery, and the fitting up of the chemical laboratory and dark-room. About March 1 actual investigation work began with the mounting of the 30-foot spectrograph in the pit and the setting up of the large electric furnace, the construction of which had been completed in the machine shop after being received from the maker. A description of the laboratory may be found in Contributions from the Mount Wilson Solar Observatory, No. 27.

The electric furnace quickly yielded results which demonstrated its superiority for spectroscopic work over any existing apparatus of the kind. The work so far carried on by Dr. King has included a study of the spectra of iron, chromium, titanium, and vanadium, as given by the furnace in vacuum at different temperatures. The effect of temperature and different amounts of vapor upon the principal lines of calcium was also observed. A series of measurements were made with an optical pyrometer to obtain the temperatures at which the various spectra were produced. Temperatures as high as 3,000° C. were measured. The spectra show almost as many lines as are given by the electric arc; while the effects of different temperatures in changing the relative intensity of lines are of high interest when considered in connection with both astronomical and physical problems. The effect of different gases in the furnace, also of high pressures and the observation of absorption phenomena, offer each a large field of work which has not yet been taken up.

During April an electric furnace of the Moissan type, inclosed in an air-tight chamber, was set up and has been used by Dr. Olmsted for the investigation of the spectra of hydrides, to be used for comparison with solar spectra in the identification of unknown lines, especially of the flutings obtained in the spectra of sun-spots. Good results for the spectra of magnesium and calcium hydrides are being obtained.

The recent discovery of the separation of lines in sun-spots, indicating the presence of magnetic fields on the sun, has led to a supplementary laboratory investigation of the Zeeman effect, the large Du Bois electro-magnet being arranged so that an electric spark between the poles may be photographed either parallel to the lines of magnetic force or at an angle to them. The magnet gives a field strength up to 36,000 c. g. s. units. Photographs are being obtained of the spectra of iron and other substances, giving an excellent separation of the spectrum lines for magnetic fields of known strength, allowing a detailed comparison with the separations obtained in the solar photographs.

Most of the laboratory investigations cover the whole range of the visible spectrum, requiring the use of photographic plates sensitive to red light in addition to those commercially obtainable. The laboratory dark-room is fitted up for the sensitizing of plates for the red region, which are thus used while perfectly fresh and are handled with the same facility as the ordinary plates.

The comparison of intensities of lines on photographic plates has been carried on by Miss Wickham of the computing division through the use of the Zeiss spectrocomparator, adapted so as to show a portion of the spectrum under examination and a specially prepared photographic scale in the field of view at the same time, giving a definite value to the intensity of each spectrum line and allowing an accurate comparison of the intensities of lines in different spectra.

COMPUTING DIVISION.

Some of the results obtained in the computing division, under the direction of Mr. Adams, have already been given. The heliomicrometer has been used by Miss Ware for all measurements of the positions of flocculi. The rapidity of measurement has been greatly increased by ruling one hemisphere of the globe with meridians and parallels 1° apart. The position of the cross-hairs, after they have been set on a flocculus, is estimated to tenths of a degree. The precision of measurement proves to be amply sufficient; in fact, the latitudes and longitudes are almost as precise as those obtained with the aid of the circles.

The measurement of the areas covered by the calcium flocculi, to serve as an index of the solar activity, has been continued throughout the year. This

PLATE 7

STEEL BUILDING AND DOME FOR 60-INCH REFLECTOR.

CUES AVNE - BOSTON

work has been carried on by Miss Smith with the aid of the special photometer devised for this purpose and referred to in the report of last year. The method of reduction which has been followed is the same as that previously described and the results obtained have proved to be fully as satisfactory as the character of the objects measured would seem to warrant. The values obtained for a period of about seven months have been platted and indicate very clearly the variation in the areas covered by the flocculi as the spot-groups pass across the surface of the sun. The time interval is of course too short to give any indication of the eleven-year period, but there is every reason to suppose that these determinations will furnish an excellent measure of the sun's activity.

The measurement of the plates used in the determination of the rotation of the sun has been done for the most part by Miss Lasby, and in addition she has devoted considerable time to the measurement of the displacements found in the spectra of the center and limb of the sun. The extension of the rotation work to include the lines of hydrogen and the line of calcium at λ 4227 has increased considerably the amount of measurement which it has been necessary to do in carrying out this research.

The definitive reduction of our plates of the sun-spot spectrum, and the identification of the unknown lines which appear on them, has involved a great amount of measurement and reduction. This work has been carried on for the most part by Miss Burwell and Miss Wickham. Miss Burwell has determined the wave-lengths of the sun-spot lines, and Miss Wickham has measured, for purposes of identification, plates of the titanium-oxide flutings obtained in the laboratory. Some idea of the amount of labor involved may be obtained from the fact that in the extent of spectrum between λ 5000 and λ 5500 there occur over 1,500 lines, whose wave-lengths in the spot spectrum must be determined and for which suitable identifications with laboratory spectra have to be found.

In addition to her work on the measurement of the titanium-oxide flutings, Miss Wickham has devoted much time to the estimation of the intensities of the lines upon the plates of furnace spectra obtained by Dr. King.

CONSTRUCTION DIVISION.

The construction division, under the superintendence of Professor Ritchey, has been occupied during the year with the erection on Mount Wilson of the steel building and dome for the 60-inch reflector; the completion of this instrument, its transportation to the mountain and its erection in the dome; the erection and equipment of the new spectroscopic laboratory in Pasadena; the construction of a spectroheliograph of 30 feet focal length and a grinding machine for the 100-inch Hooker mirror; the completion of the Mount Wilson road; and other miscellaneous work.

The instrument and optical shops were closely occupied with the 60-inch reflector during the entire year. The optical work included the grinding and figuring of the two plane and two hyperboloidal mirrors, which were tested in combination with the 60-inch mirror. In the instrument shop the mounting was completed and erected, so that the operation of all parts of the mechanism could be thoroughly tested before they were sent to the mountain. In the tests the various quick and slow motions, effected by electric motors, worked perfectly, and the mounting showed no evidences of flexure.

The experience of the previous year had shown the necessity of widening some sections of the Mount Wilson road, in order to permit the large and heavy parts of the mounting to be carried safely on the automobile truck. This work was done in the spring, immediately after the close of the rainy season. At the same time the erection of the steel building and dome was resumed. During June and July the mounting was taken to the summit without difficulty on the truck, though four strong mules were needed to assist the engine in hauling the heaviest loads, weighing 5 tons, over the steep grades. The most troublesome load was the large steel telescope-tube, 6.5 feet in diameter and 18 feet long, which was taken up as a single piece. All parts of the telescope, including the 60-inch mirror, reached the summit without the slightest injury. Work on the dome and building was completed early in September, and the erection of the telescope is so far advanced that it should be ready for use this autumn.

A spectroheliograph of 30 feet focal length, designed for use with the tower telescope, has just been completed in the instrument shop. The great linear dispersion of this instrument, and the fact that it will permit three photographs of the same region of the sun to be taken simultaneously with the light of three different lines, should prove advantageous in certain new fields of solar research. The dispersing member of this spectroheliograph is a large fluid prism, with circular faces 12 inches in diameter, which will be twice traversed by the light (Littrow arrangement).

After repeated trials the plate-glass works of St. Gobain, France, has finally succeeded in casting a suitable glass disk for the 100-inch mirror of the Hooker telescope. This is now on the way to Pasadena. As the large grinding machine, constructed for this mirror, is nearly completed, the work of grinding the disk should soon be under way.

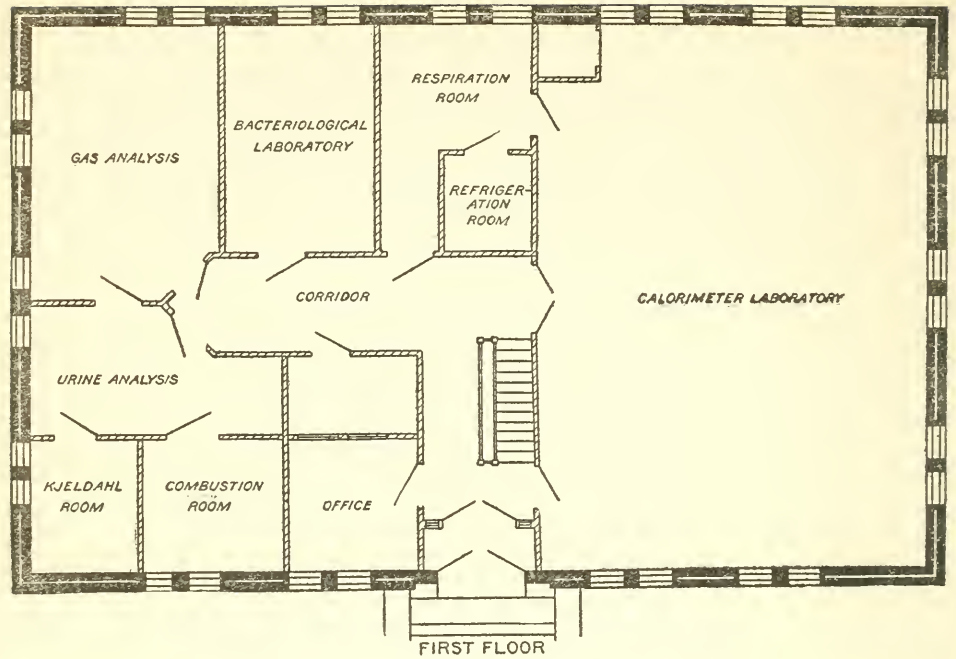
The new spectroscopic laboratory, built and equipped by the construction division, and mentioned elsewhere in this report, is described in Contributions from the Mount Wilson Solar Observatory, No. 27.

PUBLICATIONS.

The following papers have been published in the Astrophysical Journal and reprinted as Contributions from the Mount Wilson Solar Observatory:

No. 20. Spectroscopic observations of the rotation of the sun, by Walter S. Adams.
No. 21. Sun-spot bands which appear in the spectrum of a calcium arc burning in the presence of hydrogen, by Charles M. Olmsted.
No. 22. Preliminary catalogue of lines affected in sun-spots, region λ 4000 to λ 4500, by Walter S. Adams.
No. 23. The tower telescope of the Mount Wilson Solar Observatory, by George E. Hale.
No. 24. Preliminary note on the rotation of the sun as determined from the displacements of the hydrogen lines, by Walter S. Adams.
No. 25. Preliminary note on the rotation of the sun as determined from the motions of the hydrogen flocculi, by George E. Hale.
No. 26. Solar vortices, by George E. Hale.
No. 27. The Pasadena laboratory of the Mount Wilson Solar Observatory, by George E. Hale.
No. 28. An electric furnace for spectroscopic investigations, with results for the spectra of titanium and vanadium, by Arthur S. King.
No. 29. Anomalous refraction phenomena investigated with the spectroheliograph, by W. H. Julius.

The annual report of the Director was reprinted from the Year Book of the Institution and distributed with the Contributions.



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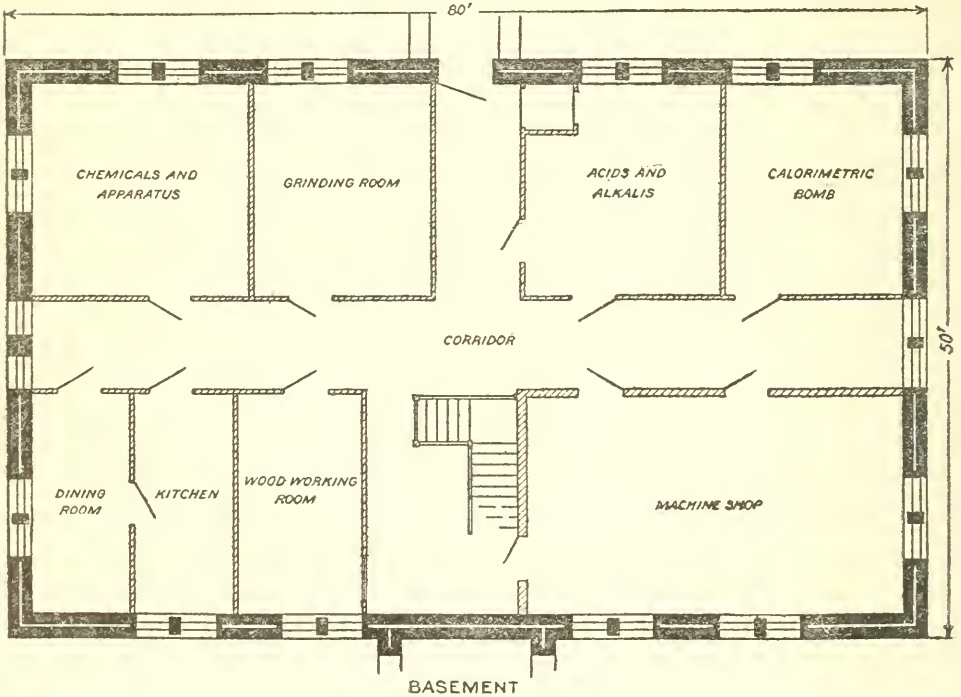
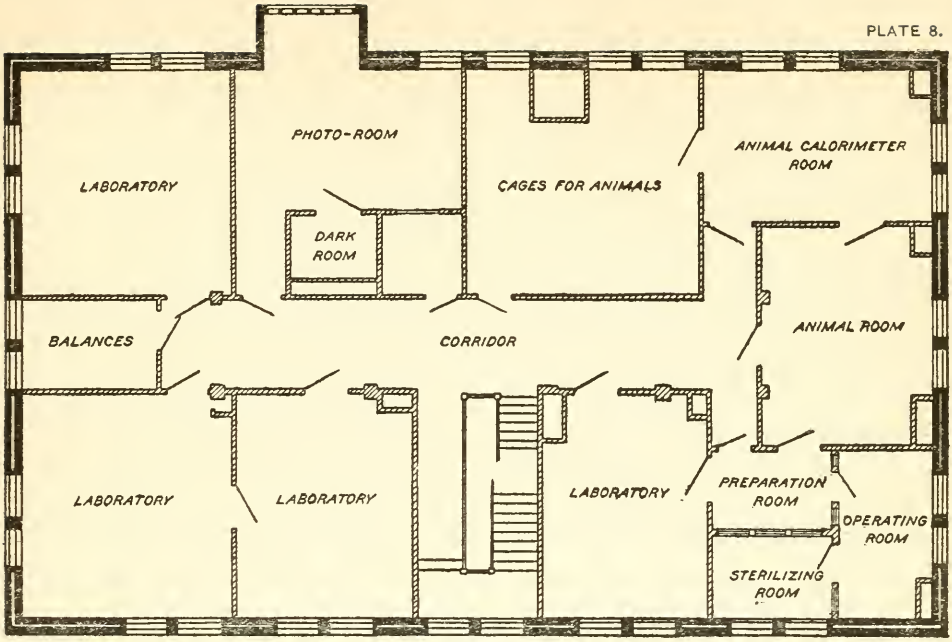


BASEMENT

PLANS OF THE NUTRITION LABORATORY.



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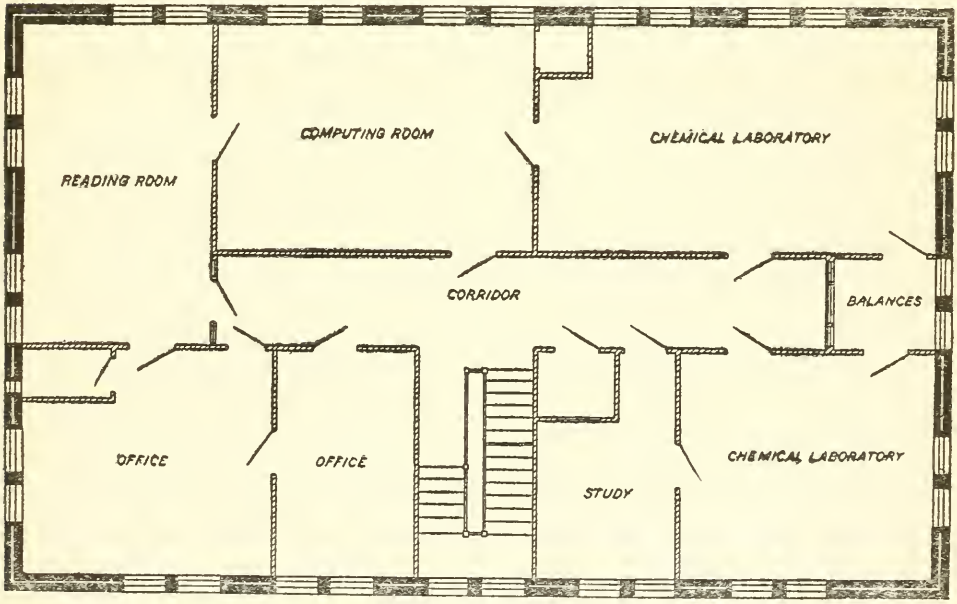

SECOND FLOOR

PLANS OF THE NUTRITION LABORATORY.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

The time of the past year has been occupied in the construction and equipment of the Nutrition Laboratory, the construction of two respiration calorimeters, the translation of important Russian monographs, and the computation of results of earlier experiments. Owing to the fact that laboratory facilities were not available until well into the spring of 1908, experimental work was impracticable.

On the definite action of the Board of Trustees to establish a nutrition laboratory, the preliminary tentative plans were submitted to Messrs. Shepley, Rutan & Coolidge, of Boston, for the elaboration of the architectural and engineering details. Shortly after the completion of the plans and specifications they were submitted for bids and the contract awarded to Messrs. Horton & Hemenway. The ground was broken early in July and the contract specified that the building was to be delivered ready for occupancy on February 1, 1908.

Site.—As a result of a careful examination of a considerable number of possible laboratory sites, a plot of ground on Vila Street, Boston, Massachusetts, was purchased from the Board of Overseers of Harvard University. The site is in close proximity to the tuberculosis hospital of the House of the Good Samaritan, the New England Deaconess Hospital, and the properties owned by the trustees of the Peter Brigham, Children's, and Rotch Hospitals.

In the near future it is hoped that the investigations with the respiration calorimeter, thus far conducted only on normal subjects, can be extended to include observations on pathological subjects, and consequently it is obvious that the close proximity of the laboratory to the large number of hospitals built or planned will facilitate in a marked degree scientific cooperation in investigating pathological metabolism.

One of the most important factors in the immediate desirability of this site was the fact that through the courtesy of the authorities of Harvard College arrangements were made whereby heat, power, light, compressed air, and brine for refrigerating purposes could be obtained at cost from the large power-house of the Harvard Medical School, situated on land immediately adjacent to the laboratory site.

Building.—As it was impracticable, owing to the cramped quarters at Wesleyan University, to continue working at that institution, a temporary wooden building was constructed on the laboratory site immediately in the rear of the laboratory building. In this building detailed plans for the new calorimeters

* Address: Vila Street, Boston, Massachusetts. Grant No. 482. For investigations and maintenance. (For previous reports on work in nutrition see Year Books Nos. 2, 3, 4, 5, and 6.)

PLATE 8

THE NUTRITION LABORATORY AT BOSTON, MASSACHUSETTS.

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were drawn and the clerical work and computations were carried on until December 1, when, owing to the excellent progress on the building made by the contractors, we were enabled to occupy two partially completed rooms on the first floor of the laboratory. One month later the contractors permitted us to occupy our offices and to begin to install machinery in the machine-shop. On February 1, 1908, the day specified in the contract, the building was transferred to the Institution essentially complete.

The occupancy of the temporary wooden building proved of great value, as thereby it was made possible for us to superintend many details of construction, to offer suggestions regarding the installation of plumbing and steam heating, and in many ways to further the rapid completion of the building, as well as to increase its efficiency. The contractors were invariably willing to accept all suggestions and spared no pains or personal expense to have the building wholly satisfactory.

Drawings of the floor plans are shown in plate 8 at the beginning of this report and a photograph of the exterior of the building is given in plate 9. The exterior is simple, but in thorough architectural uniformity with buildings in the immediate vicinity. Special attention was paid to rigid and fireproof construction and ample illumination through well-placed windows. Ornamental details are conspicuously absent, and the building appears, as the design was intended to indicate, a scientific factory.

The building is rectangular, with a basement and three stories; on each floor a central corridor, of sufficient width to permit the installation of cases for apparatus and supplies against the walls, runs the length of the building. All the inner walls, save those in the four offices on the second floor, are of plain brick, well painted. This interior construction has many advantages, since the single-thickness brick walls may be considered as brick screens, which are readily replaced or rebuilt at an expense much less than for any other form of substantial wall construction. With the compressed-air service distributed throughout the building and a pneumatic hand-drill, shelving or apparatus may be attached to these brick walls with the greatest ease and with minimum disfigurement.

Our services from the Harvard Medical School power-house obviate the necessity for boilers, coal-bins, electric lighting and power machinery, and refrigerating plant, and thus make available for experimental purposes the room that would be occupied by the installation of such machinery.

The floors of the building are reinforced 6-inch concrete slabs, giving extreme rigidity and absence of vibration. On these are laid cypress screeds, between which a fireproof filling of cinder concrete is placed. The finished floors throughout the building are of rock maple.

Two independent ventilating systems are installed, one for the removal of vitiated air from the different rooms and laboratories and the other for the

special ventilation of the hoods and toilet rooms. The main ventilating system was installed with special reference to the needs of a physiological and chemical laboratory, and for ordinary uses it is a natural gravity system. With the increase of the number of workers in the laboratory and the greater need for special ventilation, a powerful electric blower which is installed in the pent-house on the roof may be put in operation. This blower can be started and stopped from the machine-shop in the basement. A similar power blower may be used with the ventilating system connected with the hoods.

Each laboratory room is supplied with hot and cold water, high-pressure steam, electricity at 110 and 220 volts (direct current), gas, and compressed air, and hoods for the removal of noxious fumes are planned for each laboratory.

Calorimeter Laboratory.—For the most satisfactory operation of an apparatus as complicated and as sensitive as the respiration calorimeter, a special type of room was constructed. The room is 47 feet long, 33 feet wide, and 15 feet high. By means of two large girders in the third floor, it was made possible to suspend the ceiling of the calorimeter room and thus eliminate any piers or columns in the center of this room; thus the greatest freedom is afforded in the construction and assembling of the various parts of the respiration calorimeter and its accessory apparatus.

As in other calorimetric investigations, a constant-temperature room is highly desirable. Accordingly, provisions were made for permitting temperature control in this large calorimeter room. To this end, the windows and transoms are all double, the doors either of refrigerator construction or double, with air-space between, and in cold weather the room is heated by 5 steam radiators under control of 2 pendent thermostats, set at 70° F. Of special interest is the arrangement for cooling the room during the summer months, when temperatures above 72° or 73°, particularly with the high humidity experienced during summer weather, are inimical to successful experimenting with the respiration calorimeter. The temperature-control and heat-measurements of the calorimeters depend in large part upon an elaborate system of thermo-electrical elements and electrical resistance thermometers. Hence it is very important to maintain a low humidity in the air of the laboratory to avoid disturbances of the electrical connections.

Cooling during the warm weather and drying the air are accomplished at the same time by causing the air of the room to be forced by a blower over several series of brine coils, through which cold brine is forced from the power-house mains. The excessive moisture in the air is thus deposited on the brine coils and an unlimited supply of cold dry air can be returned to the calorimeter laboratory. Provisions are made for using alternate series of coils and thus allow the removal of accumulated moisture. The system has been tested and it works to complete satisfaction.

A small subsidiary brine coil permits the regulation of the temperature of a current of water used to bring away heat from the calorimeters.

Facilities for Experiments on Animals.—A special suite of rooms on the third floor is provided for metabolism experiments on animals. In order to prevent the odors from the animals reaching the rest of the building, each room in which animals are kept or in which they are experimented upon is provided with a special skylight with large windows opening directly on to the roof. The roof has a high parapet and offers an admirable opportunity for keepng small animals out of doors a good part of the year. The elevator extends to the roof, so that animals can be carried from the animal rooms to the roof without difficulty.

Photographic Room.—The large amount of new apparatus and peculiar features of experiments of the nature carried out in this laboratory necessitate some suitable place for taking photographs. Hence a photographic room, with a specially well-lighted bay and a dark-room with all proper facilities, was placed on the third floor. Heavy mains from the switchboard are connected with a stage plug in this room, allowing abundant current for an arc lamp for micro-photographic work.

Equipment.—The machine-shop is equipped with an engine lathe, a milling machine, and minor lathes and machines, thereby enabling us to do a very large proportion of our work in the building. The installation of this shop was especially planned so as to permit us to cooperate to mutual advantage with two experimental machine-shops belonging to the medical school. It is thus possible for us to construct all apparatus without the delays incidental to repairs and construction in an instrument-shop.

As a result of a careful investigation of foreign laboratories, a large number of interesting and important details in the equipment of the chemical laboratories have been introduced, and it has been found that a very large saving in time and expense may be made by constructing laboratory desks, tables, wall-cases, and shelving as needed, rather than attempt to install with an initial contract.

With reference to the equipment of the respiration calorimeter laboratory, it may be said that at the time of the closing of this report one respiration calorimeter has been built and completely tested and 12 experiments made with it. A second is rapidly nearing completion.

A large amount of apparatus specially used for studying problems in nutrition has been purchased from various laboratories abroad, and it is believed that there exists nowhere so complete a collection of special apparatus of this type as has been assembled in the Nutrition Laboratory.

The advantage of keeping in close touch with European and American investigators in similar lines by means of periodical tours of inspection has proven of incalculable benefit in the equipment of the laboratory. It has been

possible to modify many details in the construction and equipment as a result of the ideas and suggestions obtained on the tours of Mr. Carpenter and myself.

During the spring of 1908 Mr. Carpenter made a visit to a number of foreign laboratories, with a special view to obtaining details regarding the manipulation and installation of various types of respiration apparatus and was accorded every facility by the investigators in the different laboratories. His experience has been of great value in installing the new apparatus in the laboratory, and much of this apparatus is now in excellent working order.

Editorial and Computing Division.—As a result of my visit to St. Petersburg, many important researches in metabolism, both with animals and men, were discovered as inaccessible to most readers, since they were published in Russian. Believing that the material should be on record in this laboratory in available form, extensive translations have been made during the past year by Messrs. Alexander Rose and Michal Groosenberg and Miss Monossowitch. Some impression of the amount of work involved may be obtained from the fact that Pashutin's discussion of metabolism during fasting, covering 817 large Russian pages, was completely translated. Several other monographs by Likhachev, Awrorow, and Kartaschefsky are also finished.

Anticipating the delay in the accumulation of new experimental work pending the completion of the building, the computation of a large number of experiments made at Wesleyan University was reserved to occupy this time to advantage. The calculations have progressed very satisfactorily under the charge of Mr. W. H. Leslie.

It was impracticable to attempt to prepare final reports of experiments for publication until the distractions involved in construction and equipment should at least, in part, be absent.

COCKAYNE, BOSTON

THE CARNEGIE.

PLATE 10

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. Bauer, Director.

Alexander von Humboldt, in his Cosmos, was the first to fully grasp the importance of a general magnetic survey of the globe. His words are so *à propos* of the task set the Department of Terrestrial Magnetism that it may not be amiss to quote them, italicizing those sentences of peculiar interest,† viz:

> But if the laws of terrestrial magnetism are to be thoroughly investigated—that is to say, if they are to be sought in the great cycle of the periodic movement in space of the three varieties of magnetic curves—it is by no means sufficient that the diurnal regular or disturbed course of the needle should be observed at the magnetic stations, which since 1828 have begun to cover a considerable portion of the earth's surface, both in northern and southern latitudes; *but four times in every century an expedition of three ships should be sent out, to examine as nearly as possible at the same time the state of the magnetism of the earth, so far as it can be investigated in those parts which are covered by the ocean.* * * * Land expeditions should be combined with these voyages, in order, where masses of land can not be entirely traversed, to determine at what points of the coast-line the magnetic curves (especially those having no variation) enter. * * *
>
> Since the memorable Antarctic expedition of Sir James Clarke Ross (1839–43), fitted out with admirable instruments, has thrown so much light over the polar regions of the Southern Hemisphere, and has determined empirically the position of the magnetic south pole; and since my honored friend, the great mathematician, Frederick Gauss, has succeeded in establishing the first general theory of terrestrial magnetism, we need not renounce the hope that the many requirements of science and navigation will lead to the realization of the plan I have already proposed. *May the year 1850 be marked as the first normal epoch in which the materials for a magnetic chart shall be collected; and may permanent scientific institutions (academies) impose upon themselves the practice of reminding every twenty-five or thirty years governments, favorable to the advance of navigation, of the importance of an undertaking whose great cosmical importance depends on its long continued repetition.*

This plan of Humboldt's, as well known, never came to a realization and, instead, the work hitherto has consisted of more or less isolated and incomplete surveys, independently undertaken by various nations and distributed over a great many years. Not even for a single epoch has it been possible to construct magnetic maps on a plan of concerted action, to say nothing of the impossibility of drawing them for several epochs 25 or 30 years apart.

It was certainly high time, therefore, that a plan universally conceded to be of the highest importance, which, for one reason or another, had failed of

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* Address: The Ontario, Washington, District of Columbia. Grant No. 481. $57,000 for investigations and maintenance. (For previous reports see Year Books Nos. 3, 4, 5, and 6.)

† The quotation is taken from E. C. Otté's translation of the Cosmos, vol. II, 1849, pp. 719–720.

execution on a concerted international basis, be attempted, with the friendly and effective cooperation of those interested, by a research organization provided with sufficient means to bear the chief brunt of the work. The present report records the progress made in this undertaking during the fiscal year November 1, 1907, to October 31, 1908.

MAGNETIC SURVEY OF THE PACIFIC OCEAN.

The magnetic survey yacht *Galilee,* employed since 1905 in the Pacific Ocean work, at the close of the previous fiscal year was on her way from Honolulu to Jaluit, of the Marshall Islands. She was off Midway Island October 5, 1907, and arrived at Jaluit October 21, the same port was visited in 1906. Having completed the shore and harbor work, she set sail on October 31 for Port Lyttleton, New Zealand. November 1 found the vessel becalmed in the Lagoon of Jaluit and in a very dangerous position because of the many reefs and the lack of any auxiliary power. For 11 days she lay thus, being aground on a reef at one time for a period of several hours, when the opportune arrival of the German mail steamer offered a means of towage out to sea. Course was then laid directly for New Zealand via Cook's Strait. In this leg of the cruise, the lack of auxiliary power was again sorely felt, when for 4 days every effort had to be made in order to keep clear of the New Hebrides Islands by reason of contrary winds. Port Lyttleton was reached late in the afternoon on the day before Christmas. Lieutenant Shackleton's Antarctic Expedition in the *Nimrod* was found just in the midst of final preparations for departure. This fact, in connection with the holiday season, delayed work until the very end of the month. The New Zealand government, through the premier, the Rt. Hon. Sir Joseph G. Ward, and the Port Lyttleton Harbor Board, extended to the *Galilee* party every possible courtesy and aid, giving not only free wharfage but also transportation facilities on the railways and the service of a tug for use in swinging, and putting the facilities of the Christchurch Magnetic Observatory at its disposal. Dr. C. Coleridge Farr, of Canterbury College, and Mr. H. F. Skey, director of the Christchurch Magnetic Observatory, rendered the party every possible assistance.

Upon completion of the instrumental comparisons at the Christchurch Observatory, and of the shore observations, the *Galilee* was swung off New Brighton Beach. Departure from Port Lyttleton was made on January 17, 1908, and the course followed was practically along the parallel of 43° south to about west longitude 108°, from which point the course was generally northeast until arrival in Callao Bay, Peru, on March 10. In this passage from New Zealand, violent gales were encountered between February 7 and 11, the vessel scudding at one time before the wind under bare poles, but thanks to her capable and experienced sailing master, Capt. J. T. Hayes, she safely outrode every gale, though somewhat the worse for wear. At Callao a

delay of some two weeks was incurred by the necessary repairs, chiefly of the rudder. The land and sea work being completed at this port, the *Galilee* entered on the last and final leg of her cruises, setting sail on April 5 for latitude 1.5° south and longitude 114° west, whence a north course was followed to latitude 12° north. From this position the track followed was almost a direct one to about 31° north latitude in 137.5° west longitude, from which point course was set for the Golden Gate. San Francisco was reached on May 21, 1908, thus concluding Cruise III, begun at San Diego on December 22, 1906, and having a total length of about 35,000 nautical miles. The necessary swings and land observations for properly closing the work having been made, the vessel was returned to her owners on June 5, 1908, and the various instruments and appurtenances forwarded to the office at Washington.

Cruise III thus exceeded in length the combined total (26,000 nautical miles) of Cruises I and II. Twelve harbors were visited; at all of these extensive shore observations and intercomparisons of ship and land instruments were made; in three of the harbors swinging ship could not be done, either by reason of lack of tug facilities or of insufficient depth of water. Twenty primary land stations at the following points were established: Coronado Beach Island, San Diego, California, U. S. A.; Nuka Hiva Island, Marquesas Islands (2 stations); Papeete, Tahiti Island, Society Islands; Mota Uta Island, Papeete Harbor, Society Islands; small coral island in Papeete Harbor, Society Islands; Apia Magnetic Observatory, Samoan Islands; Tarrang Island, Tomil Bay (Yap Island), Caroline Islands; Zi-ka-wei Magnetic Observatory, Shanghai, China; Woosung, China (2 stations); Sitka Magnetic Observatory, Alaska; Kutkan Island, Sitka Harbor, Alaska; Honolulu Magnetic Observatory, Hawaiian Islands; Jaluit, Marshall Islands; Christchurch Magnetic Observatory, South Island, New Zealand; New Brighton Beach, South Island, New Zealand; San Lorenzo Island, Callao Bay, Peru; Goat Island, San Francisco Bay, California, U. S. A., and San Rafael, California, U. S. A.

In addition to these primary stations, there were established in the neighborhood of the same in all 20 secondary stations for the purposes of intercomparison and standardization of ship's instruments. Swings for the determination of ship's constants and deviation factors were made at the following harbors: San Diego Bay, Papeete Harbor, mouth of the Yangtse River, Sitka Harbor, Pearl Harbor (off Honolulu Magnetic Observatory), Jaluit Lagoon, off New Brighton Beach, Callao Bay, and San Francisco Bay. At these points 13 complete swings (both port and starboard helms) on 8 points were made, each involving complete observations of the three magnetic elements.

While at sea during Cruise III in addition to the course observations, which were made as frequently as weather and sea conditions permitted, swings, under sail, covering 6 to 8 points, were carried out as follows: 21 for

declination on both helms and 3 on one helm; 34 for horizontal intensity by deflector on both helms and 4 on one helm; 17 for intensity by Lloyd-Creak dip-circle on 2 helms and 17 on one helm; and 17 for dip on one helm, in addition to which dip values were derived from the intensity work with the Lloyd-Creak dip-circle on 34 swings of one helm each.

Astronomical observations for position with dead reckoning, involving some 1,600 observation and computation sheets, daily intercomparisons of 5 chronometers, and daily meteorological observations were made. Experiments were carried out in connection with a design suggested by the commander of the *Galilee,* of a "collimating liquid compass" for sea work, which seem to indicate the feasibility of such an arrangement for the improvement of the magnetic-declination work. Further experimentation is being made in the instrument division of the Department. Some experiments were also made for improvement in the methods of intensity observations at sea.

In addition to his duties as magnetic observer, Mr. P. H. Dike made observations of the electrical condition of the atmosphere at sea, whenever conditions and time permitted. His report, summarizing the results obtained, will be found in the September issue of the Journal, "Terrestrial Magnetism and Atmospheric Electricity." The conclusions drawn are:

While the work done has served mainly to point out the difficulties to be encountered in using the present types of electrical instruments at sea, still some information has been accumulated which may be of value in connection with future work undertaken in similar fields. Also, the probability that the earth-air electric current is of the same order of magnitude over the sea as over the land has been strengthened. In the neighborhood of land, as off the coast of Alaska and in Cook Straits, the observations showed conclusively the presence of radioactive emanation in the air, but in the open sea there is but little evidence. Rain-water, caught as it fell and immediately evaporated to dryness, showed no sign of radioactivity.

The personnel of the *Galilee* party remained the same throughout the portion of Cruise III here concerned, viz, William J. Peters, commander; P. H. Dike and D. C. Sowers, magnetic observers; Dr. G. Peterson, recorder and surgeon; and J. T. Hayes, sailing master. The volume of work accomplished, as well as its high quality and the promptness in reduction and forwarding of the observations, all bear ample testimony of good management on the part of the leader and of the hearty and effective cooperation of every member of the party.

The return of the *Galilee* to her home port, San Francisco, after an absence of nearly 3 years, during which time she has cruised in the Pacific Ocean, as shown on plate 11, to the extent of over 60,000 nautical miles, in regions where magnetic data were very scarce, brings to a conclusion the first portion of the ocean magnetic work. During this period, a general magnetic survey of the greater part of the Pacific Ocean has been accomplished. It may con-

fidently be expected that the results soon to be derived from this work, besides furnishing navigators with more correct magnetic charts than hitherto available, will assist materially in solving some of the vexed problems of the distribution of the earth's magnetism. With the aid of the land work conducted simultaneously with the ocean work by the Institution and other organizations, it will soon be possible to construct a new set of magnetic charts for nearly one-third of the globe, as based almost exclusively on freshly acquired and homogeneous magnetic data.

There is also cause for gratification at the rare good fortune which has attended the execution of the ocean work thus far. Throughout the period of work (1905–8) the vessel, an all-sailing one with no auxiliary power, though exposed at times to imminent danger, met with but one accident, viz, when she was dashed by a typhoon against the breakwater at Yokohama, August, 1906, and was partially sunk in 14 feet of water. Ten days after this accident, however, she again set sail for a lengthy cruise to San Diego, California. Not a single loss of life in her personnel is to be recorded.

The experience gained proved conclusively that for the most economical, expeditious, and satisfactory execution of the ocean magnetic survey, it would pay to suspend now the work, return the chartered vessel to her owners, and undertake the construction of a vessel designed wholly with the special needs in view.

The authorization of the building of such a vessel by the Executive Committee of the Carnegie Institution of Washington should surely be a source of encouragement and stimulus to every investigator in magnetic science. A brief description of the proposed new vessel, to be called the *Carnegie,* in accordance with the action of the Executive Committee follows. Acknowledgment should be made of the substantial and valuable assistance rendered by Dr. Charles Lane Poor, of Columbia University, in the settlement of some very important details in the plans of this vessel.

THE NEW MAGNETIC SURVEY YACHT, THE "CARNEGIE."

The principal dimensions of this vessel are to be: Length over all, 155 feet 6 inches; length on load water-line, 128 feet 4 inches; beam, molded, 33 feet; depth of hold, 12 feet 9 inches, with a mean draught of 12 feet 7 inches, and a displacement of 568 tons with all stores and equipment on board. All the materials entering into the construction of the vessel are to be non-magnetic and to be of the very best of their kind.

The hull will be constructed of wood; the keel, stem, sternpost, frames, and deadwood to be of white oak, the beams and planking of yellow pine, and the deck of Oregon pine. The fastenings are to be locust treenails, copper and Tobin bronze bolts, and composition spikes. All deck-fittings and metal-work on spars and rigging will be of bronze and copper, and the rigging will be of hemp.

The vessel will have full sail-power, being rigged as a brigantine, carrying just under 12,900 square feet of plain sail. In addition to this there will be an auxiliary power plant, constructed of non-magnetic materials as far as possible and consisting of a 6-cylinder internal-combustion engine capable of developing 125 indicated horsepower at 350 revolutions per minute, which, driving a feathering propeller of special design, will give the vessel a speed of 6 knots in calm weather. The engine will be operated by gas generated in a producer gas-plant. The vessel will carry 25 tons of coal in her bunkers, which will give her a cruising radius of 2,000 nautical miles at a speed of 6 knots.

All living quarters will be below, the ventilation and lighting to be obtained by means of a cabin trunk on deck about 42 feet 8 inches in length, 16 feet 6 inches in width and 3 feet in height, and safety will be secured by means of 6 transverse watertight bulkheads dividing the vessel into 7 compartments. The sailing officers' and crew's quarters will be forward, 42 feet in length and occupying the full width of the vessel; next will be the quarters for the scientific staff, 38 feet in length and extending the full width of the vessel; and abaft of this will be the machinery space 23 feet in length. The living quarters have been planned to give good accommodations for all, and will be fitted with all necessary conveniences for long cruises.

The observation room and magnetic observatories are located on main deck amidships, and consist of a central observation room with circular observatories forward and aft of it. The observation room will be 14 feet 6 inches long and 16 feet wide, and the observatories will be circular, 7 feet 6 inches in diameter, each fitted with a revolving dome, constructed of bronze framework and plate-glass and arranged so as to permit, whenever possible, sighting on celestial or terrestrial objects in magnetic declination work. The joiner-work will be in white pine painted, with hardwood trimmings finished bright.

The general principle followed in the arrangement of the magnetic instruments is to locate them where the effect of the magnetic material necessarily remaining in the machinery, etc., will be of the order of the error of observation, and to secure independent, duplicate determinations of each magnetic element, as far as possible.

The plans and specifications have been prepared, in consultation with the Department, by Mr. Henry Gielow, naval architect and engineer, of New York City. The construction is to be begun in December, 1908, and the date set for completion is July 1, 1909.

Plate 10, showing the *Carnegie* as she will appear under sail, was prepared from a wash drawing made to scale from the working plans by the New York artist, Mr. C. McKnight Smith, under the direction of the naval architect, Mr. Gielow.

CRUISES OF THE MAGNETIC SURVEY YACHT "GALILEE" FROM AUGUST 1, 1905, TO JUNE 1, 1908

(TOTAL LENGTH ABOUT 60,000 NAUTICAL MILES)

DOTTED LINES SHOW TRACK OF "CHALLENGER" EXPEDITION, 1872-1876

FUTURE OCEAN MAGNETIC WORK.

In the expectation that the new vessel will be available about the middle of 1909, the present plans contemplate as the first regions of work the North Atlantic Ocean and Hudson Bay. Certain land work, as elsewhere related, was undertaken this summer with these ends in view.

MAGNETIC SURVEY OF LAND AREAS.

The magnetic survey of the more or less unexplored areas has been as vigorously continued as the means and available observing force permitted. Special acknowledgment is due to the substantial and effective aid rendered by various governments and cooperating institutions. Manuscript results of observations recently made in Mexico, Canada, and the outlying islands of New Zealand were received from the respective directors in charge (Señor Felipe Valle, Mexico; Dr. King, Ottawa; Professor Stupart, Toronto, and Messrs. Farr and Skey, New Zealand).

Through the appointment by the Executive Committee of Dr. J. C. Beattie (Director, Department of Physics, South African College, Cape Town) as Research Associate of the Department for 1908–9, magnetic work in certain unexplored regions of Africa is assured for the coming year. Up to the end of the present year his time will be consumed in preparation and instrumental tests. He expects to set out in November, and will be assisted by Professor J. T. Morrison, of Victoria College, Stellenbosch, Cape Colony.

British North America.—Magnetic Observer J. P. Ault was engaged for the summer and assigned to work in Canada, leaving Washington July 5 with Mr. C. C. Stewart as a member of his party. After observing at Winnipeg, the party outfitted at Prince Albert, Saskatchewan, for a trip by canoe as far as the sixtieth parallel, if possible, via Cumberland House, Reindeer Lake, Lac Du Brochet, and Sandy Lake. Up to September complete magnetic observations had been secured at the following points: Cumberland House, Sturgeon's Tent, Scoop'em Rapids, Pelican Narrows, Frog Portage, Two Rivers, Deer's Lake, Spruce Rock, Antoine's Bay, Lac Du Brochet, Jack Fish Lake, Husky Post, Husky Portage, Canoe Limit, The Pas (Lefroy's station of 1843). In the course of this trip, embracing 68 days, 1,600 miles were covered by canoe and 71 portages, varying from 100 yards to 2 miles, were made, a feat entailing no little endurance, perseverance, and hardship; the desired parallel of 60° was reached. Various experiences encountered showed the pluck and resources of the party. Hudson Bay Junction was reached from The Pas by handcar on September 6 and observations were made there. From here the party returned to Prince Albert, from which point the work was continued by Mr. Stewart, 7 stations having been occupied in the province of Saskatchewan, 4 in Manitoba, 4 in Alberta, and 1 in

Ontario. Mr. Ault, having thus most satisfactorily accomplished the mission intrusted to him, returned to Washington September 18 and then resumed his college work at Columbia University, New York. Mr. Stewart continued in the field until the end of the year. This expedition was made possible through the good offices of Mr. C. C. Chipman, Commissioner of the Hudson's Bay Company at Winnipeg, and the representatives of the company at the various posts. The results obtained will afford valuable secular variation material in connection with the extensive work of Lefroy during 1842 and 1844, and in a large measure they cover a region where no observations previously existed.

British North America and Arctic Regions.—By special arrangement with Commander Peary, who for a stated sum agreed to furnish all required facilities, the Department was able to assign one of its observers, Mr. C. C. Craft, on the auxiliary supply-ship, the *Erik,* thus securing magnetic observations at 2 stations in Nova Scotia, 2 in Newfoundland, 3 in Labrador, 3 in Baffin Land, and 9 in Greenland, extending almost to the eightieth parallel of latitude. Not only were new magnetic data obtained, but important secular variation results as well along the entire route traversed. The *Erik* left Sydney, Cape Breton, on July 15, and returned to Brigus, Newfoundland, September 30.

A cooperative arrangement was entered into with the Canadian Department of Marine and Fisheries for securing magnetic and allied observations on an eighteen months' cruise of the *Arctic* (formerly the *Gauss*) to Baffin Land, Davis Strait, Lancaster Sound, Barrow Strait, and Melville Sound. For this purpose the Director conferred with the Minister of the Department at Ottawa, Professor R. F. Stupart, Director of the Canadian Meteorological Service, at Toronto, and Capt. J. E. Bernier, Commander of the *Arctic,* at Quebec. The result was that the Minister detailed to the *Arctic* Mr. W. E. W. Jackson, an experienced magnetic and meteorological observer of the Canadian Meteorological Service; this Department supplied the outfit of magnetic and electric instruments, gave such additional training (July 8–12) to Mr. Jackson at Washington as he required, and furnished all necessary observation forms and data, as also full directions for the contemplated work. It was decided to confine the magnetic work chiefly to work ashore and on the ice. The *Arctic* left Quebec on July 29, 1908, and it is confidently believed that in view of the interest shown in the work by Commander Bernier and Mr. Jackson valuable data will be secured.

Canal Zone, Colombia, Barbados, and Guiana.—Mr. H. W. Fisk, magnetician, entered on field duty in the early part of July. En route to South America he reoccupied the Department's magnetic stations on shore of Limon Bay, near the north entrance of the Panama Canal. He occupied two stations in Colombia, viz, Cartagena and Savanilla (Puerto Colombia), and in

Barbados observations were made at Bridgetown (Department's station of 1905) and at Bathsheba. Up to October 4 Mr. Fisk had occupied 15 stations in British Guiana, and during remainder of the month was engaged in magnetic work in Dutch Guiana and French Guiana.

China.—At the end of October, 1907, Dr. C. K. Edmunds, occasionally on duty as magnetic observer, was in the field in the interior of China in the Province of Hupeh. Continuing in the field until December, he made further observations at the following points: Hankow, Hupeh; Kiukiang, Kiangsi; Changsha, Hunan; Hengchowfu, Hunan; Yungchowfu, Hunan; Kweilin, Kwangsi; and Wuchow, Kwangsi. He then returned to his duties with the Christian College at Canton. He resumed field work in the eastern part of China October 1. There has been completed thus far by him a fairly detailed magnetic survey of the southeastern part of the Chinese Empire, between approximately the meridians 113° and 122° east and parallels 22° and 42° north.

Mr. Don C. Sowers, formerly a member of the ocean party, was placed in charge of a special magnetic expedition. His operations will extend from Peking westward, in the vicinity of the fortieth parallel, through China, inclusive of Chinese Turkestan, thence crossing the Himalayas via the Karakorum Pass, and closing work at one of the base stations of the India Magnetic Survey. In the portions of China to be penetrated, no magnetic observations whatever have thus far been made. Having completed all necessary preliminary arrangements, Mr. Sowers left Washington at the end of October to enter upon this extremely important work.

Ecuador and Jamaica.—Mr. Edward Kidson, at one time assistant to Dr. Farr at the Christchurch Magnetic Observatory, was appointed a magnetic observer on March 1, 1908, and assigned during March and April for further training and to assist Mr. H. F. Skey (Director of the Christchurch Magnetic Observatory) in the magnetic survey of the Chatham Islands, the expense of which, outside of the services of Mr. Kidson, was borne by the New Zealand government. Complete observations were thus made at 15 stations, the results of which have been courteously supplied to the Department by Mr. Skey. Mr. Kidson next reported at Washington on June 10, and, after securing further instruction in the methods and instruments used by the Department, left in July for magnetic work in South America. En route in company with Mr. Fisk he secured some observations at the Department's station, Kingston, Jamaica.

Towards the close of the year he had completed observations at 9 stations in Ecuador, and was extending the work northward to Quito, from whence he will proceed overland to Bogotá, Colombia. He has received valuable assistance from both the British and American diplomatic officials.

Egypt, Turkey, Russia, and Persia.—During the latter part of February Mr. J. C. Pearson, magnetic observer, sailed from New York for magnetic work in Turkey, Egypt, Russia, and Persia. En route he made extensive comparisons between his outfit and the standards of the Kew Magnetic Observatory of the National Physical Laboratory at Richmond, Surrey, England. His results have given further confirmation to the general correctness of the provisionally selected International Magnetic Standard adopted by the Department (see Journal of Terrestrial Magnetism and Atmospheric Electricity, vol. XII, No. 4, pp. 161–165).

Upon arrival in Turkey, Mr. Pearson, with the permission of the Turkish Government, made magnetic observations in the vicinity of Constantinople at Rumeli Hissar, in the grounds of Robert College, on the European shore of the Bosphorus, and proceeded thence to Egypt. Here another valuable observatory comparison was obtained, viz, near Cairo, at the Helwan Observatory of the Survey Department of the Ministry of Finance of Egypt. He also secured valuable data for secular variation purposes at Port Said, Suez, and Alexandria.

Mr. Pearson returned again to Constantinople and set out for the work in Persia, via Tiflis, Russia. En route through Russia observations were made at Batum, a secular variation station, another observatory comparison was secured this time at the Tiflis Magnetic Observatory, situated at Karsani, near Mtskhet, Caucasus, and further observations were made at Alexandropol, Erivan, and Nakhitchevan. Every courtesy was shown him by the officials in charge of the observatories at Helwan, Egypt, and Tiflis, Russia.

Provided with the necessary credentials by the representatives of the Persian Government at Washington and Constantinople, and furnished by the Russian Minister of Foreign Affairs at Tiflis with special letters to the various Russian representatives in Persia, he entered that country, via the northern frontier, and made observations at Khoi and at Tabriz. At the latter place he was detained by the revolutionary troubles from July 8 to August 18. Conditions having somewhat improved, he secured the necessary caravan outfit and set out on August 18 for Teheran, where he arrived October 5, securing magnetic results at 4 stations en route. From Teheran the work is being extended southward.

Through the kind offices of the American ambassador at Constantinople, Mr. Pearson secured the services, as interpreter and assistant, of Mr. Dimiter V. Pehlivanoglou, who speaks English, French, Spanish, Greek, and Turkish, and who has some knowledge of Arabic and Persian. Mr. Pearson deserves no little credit for the manner in which he has conducted the important and difficult work entrusted to him. Most valuable assistance was rendered him by the American consul at Tabriz, Mr. Doty.

West Indies and Central America.—Mr. W. H. Sligh, newly appointed a magnetic observer, was assigned at the close of the year to complete the work in these countries begun by Mr. Ault in 1905 and continued by Mr. Fleming in 1907. Mr. Sligh has completed the preliminary arrangements, and for the purpose of securing some additional experience made magnetic observations at some stations in Maryland under the direction of Observer Stewart. He will leave Washington for the West Indies early in November, 1908.

OFFICE AND EXPERIMENTAL WORK.

It may be readily appreciated that with such world-wide field operations in progress, as described in the foregoing pages, the time of the office force is largely consumed with executive and administrative matters. Much time has been given to the determinations of constants and corrections for the various instrumental outfits required for land and sea work. As the result of rigid tests made with regard to magnetic impurities in outfits, the corrections of the various magnetometers to an international standard have been reduced to a minimum. The imperfections as they were found could be immediately remedied in the instrument shop of the Department, established in January, the usefulness of which has been amply demonstrated. A great amount of repair and detail instrument work could thus be expeditiously undertaken under direct supervision. The services of Mr. Adolf Widmer were secured as mechanician in charge; he has shown himself both efficient and capable. It is hoped that before long the Department will be able to make the magnetic instruments required almost exclusively in its own shop, an advantage which every experienced magnetician will readily appreciate.

Plans and experiments for the construction of special ship instruments, already above referred to under ocean work, are at present in progress.

In cooperation with the special investigations of the Director of the Mount Wilson Solar Observatory as to the relation between certain solar and terrestrial magnetic phenomena, Dr. W. G. Cady has made some further improvements in the direct-recording declinograph installed at the Observatory.

As in the past, the current observations have been reduced as received in order to promptly correct any defects in instruments or methods. Excellent progress has been made with the preparation for publication of the results of all observations (on land and at sea) thus far made by the Department, and it is hoped that by the end of the calendar year the manuscript for the first volume of Magnetic Results of the Department will be ready for the press.

Material assistance has been rendered, in cooperation with the U. S. Coast and Geodetic Survey, in the completion of the special publication by the Director on the results of the magnetic survey of the United States and magnetic maps for January 1, 1905; this publication is now in the hands of the

Government printer. At the request of the President and with the permission of the Superintendent of the Coast and Geodetic Survey, a brief summary of the results was presented by the Director before the meeting of the National Academy of Sciences last April.

Considerable time has been devoted to a careful consideration of the projected plans of the new vessel and to making preliminary computations of possible magnetic effects to be expected from the amount of magnetic material necessarily remaining in the machinery, etc.

Public addresses have been made by the Director on the Pacific Ocean Magnetic Survey before the Middletown Scientific Association, at Wesleyan University, February 10, and at Columbia University on February 11, in the course on "Navigation and nautical science"; as also in Philadelphia, April 25, at the special request of the president of the American Philosophical Society. For other papers presented before scientific societies, see bibliography.

Capt. Roald Amundsen, the noted explorer, visited the office in November and conferred with the Director regarding the magnetic work on his Northwest Passage expedition and as contemplated in his future polar work. Visits have also been received from other noted men interested in magnetic science who have familiarized themselves with the work of the Department.

The compilation of past magnetic data, the index of current literature, have been continued, and abstracts of publications of special interest have been prepared from time to time. Publications pertaining to the work of the Department have been forwarded regularly to interested parties and organizations in all parts of the world.

Due credit must be given Mr. J. A. Fleming, magnetician-in-charge, for the efficiency secured in the administration and execution of the office and experimental work.

ARCHEOLOGY.

American School of Classical Studies at Athens. James R. Wheeler, Chairman of Managing Committee, Columbia University, New York, New York. Grant No. 485. (*a*) *Excavations at Corinth,* $1,500. (*b*) *Maintenance of a fellowship in architecture at Athens,* $1,000. (For previous reports see Year Books Nos. 4, 5, and 6.) $2,500.

(*a*) *Excavations at Corinth.*—The grant for excavation has as usual been expended at Corinth. Some digging was done about the already uncovered fountain of Pirene, and further study was given to the ruins. Two of the four large water-storage chambers which exist behind the fountain were cleared out, and the early structure, dating at least from the sixth century B. C., was thus made plainer. The limits of the first Roman court in front of the spring were determined, with the water channels which led to the basin. This work made clear the structure of the so-called "open-air fountain" mentioned by Pausanias. Excavations were made also on the west side of the "market place," and a row of early Roman shops was uncovered. These rest on the line of a Greek terrace. One of the temples (Roman) mentioned by Pausanias as "on the Agora" was discovered, a fact which makes it certain that a number of other structures mentioned by him lie under a mass of earth in the northwest part of the market place. The uncovering of the end of the so-called "northwest stoa" (third century B. C.) revealed the perhaps unique use (for this date) of cement in the setting of the stones. Cramps, however, were also used in the wall, so that the cement was apparently intended to check the infiltration of water. The limits of the precinct of the great Temple of Apollo are now fixed by these excavations in the market place.

A small excavation at the theater has established the size of the building. The radius of the *cavea* measures 65 meters. There are indications of some interesting and unusual features in the structure, but the great cost of work at this point prevented further digging.

Some Roman sculpture was unearthed in the course of the excavations. A few pieces are interesting, but most of it is of little artistic merit. On the other hand, much good pottery was found, including Geometric, Proto-Corinthian, Corinthian, and Attic black-figured vases. One excellent "Fikellura" vase also was unearthed; this is of great interest, since it is a visible evidence of early trade relations between Ionia and Corinth. Terra-cottas also occurred, dating from the earliest times down, and an interesting and well-preserved mold of a head of the Athena Parthenos type was found. This is from the remains of the Greek theater which lie under the Roman theater already mentioned, and it is important both artistically and as an indication of the date of the stratum in which it was found.

A general view of the present state of the excavations is shown on plate 12, and it is hoped that this may make the condition of the work at Corinth clear to the eye. In spite of the delay which has already occurred in issuing the extended bulletin on the excavations, which is in preparation, it has seemed wise to hold this back a little longer, that the most recent views on several subjects may be presented in it.

The Director of the school, Mr. B. H. Hill, has continued his study of the important little sanctuary previously uncovered and dating from Greek times, in which arrangements appear to have been made for mysterious oracular responses. This seems to be an important discovery for the study of similar religious practices.

(*b*) *Fellowship in Architecture.*—Mr. H. D. Wood, Fellow in Architecture, has prepared a careful plan of the field of excavation at Corinth. Mr. Wood has also made a study of a Roman stoa of considerable importance. He has also continued his study of the Propylæa at Athens, the results of which are of distinct scientific merit. These are soon to be published in the Journal of Archeology.

Mr. Wood is obliged to return to this country next year, and Mr. William B. Dinsmoor has been appointed to succeed him as Fellow in Architecture. Mr. Dinsmoor is a graduate of Harvard, and has already published (Journal of Archeology, 1908, Nos. 1 and 2) a valuable architectural study of the Mausoleum at Halicarnassus.

American School of Classical Studies in Rome. Andrew F. West, Chairman of Managing Committee, Princeton University, Princeton, New Jersey. Grant No. 486. (*a*) *Maintenance of two research fellowships in classical archeology,* $1,600. (*b*) *Publication of results of scientific investigation,* $1,000. (For previous reports see Year Books Nos. 4, 5, and 6.) $2,600.

(*a*) During the year 1907–08 Dr. Esther B. Van Deman and Dr. Elias W. Loew held positions under the grant. They have been continuously engaged in research. Dr. Van Deman has published a paper on "The value of the vestal statues as originals," in the American Journal of Archeology, 1908, Part III. Her work on the Atrium Vestæ has been brought to a conclusion and is in process of publication. Dr. Loew continued his studies on the Lambardio manuscripts, in preparation for publication of a historical examination of the script. In June, 1908, he published a monograph entitled "Die ältesten Kalendarien aus Monte Cassino," in the Quellen und Untersuchungen zur lat. Philologie des Mittelalters. Prof. J. B. Carter, the director of the school, is very much encouraged by the gratifying scientific results so far secured.

PLATE 12

WRAYNE, BOSTON

GENERAL VIEW OF THE AMERICAN EXCAVATIONS AT CORINTH

(*b*) The school published volume II of its Supplementary Papers in the spring of 1908. The volume consists of four treatises, embodying important results of original research conducted by members of the school. The four treatises are as follows:

The advancement of officers in the Roman army, by George H. Allen.
Roman monumental arches, by C. Densmore Curtis.
The palimpsest of Cicero De Re Publica, by Albert William Van Buren.
Inscriptions from Rome and Central Italy, by James C. Egbert.

The scientific productivity of the school has become so considerable that in editing this second volume it was possible only to make a selection out of many papers. Some of the shorter papers have been published elsewhere, as mentioned in the prefatory note to the second volume, but important papers still remain for publication and others are in course of preparation.

Brigham, William T., Bernice Pauahi Bishop Museum, Honolulu, Hawaii. Grant No. 341. *Surveying, photographing, and describing the heiau, or ancient stone temples of the Hawaiians, in connection with a treatise on "Ancient Hawaiian Worship."* (For previous reports see Year Book No. 5, p. 58, and Year Book No. 6, p. 171.) $2,500.

Dr. Brigham reports that he has been unable to complete his survey of the old Hawaiian temples this year, owing to his inability to secure the necessary assistance in the field work. He expected before the end of the year, however, to make a personal investigation of the probable site of a temple to Pele, near the active volcano of Kilauea. Considerable work has been done during the year in sifting the various legends, often conflicting, attaching to the deserted temples. Dr. Brigham states that when he has before him the plans of all the existing ruins he will need little time to formulate his final report.

Ward, William H., 130 Fulton Street, New York, New York. Grant No. 306. *Completion of study of oriental art recorded on seal cylinders of Western Asia and Egypt.* (For previous reports see Year Books Nos. 2, 3, 4, and 5.) $250.

During the year Dr. Ward has completed the study of the oriental seal cylinders, and has transmitted to the Institution the manuscript of a large volume with 1,300 drawings, mostly of cylinders, but a limited number of them of other objects, such as bas-reliefs, for comparison. Of these about half have never before been published. They add greatly to the material for study, and much labor has been given to the interpretation of the scenes figured and the identification of the gods. The seals are classified by age and nationality, whether archaic, from a period as early as 3500 B. C., or of the Middle Babylonian, or the later Assyrian and Persian periods, to a time as

late as 500 or 400 B. C. By nationality they are classified as Babylonian, Assyrian, Persian, Hittite, Syrian, and Phenician. They are also classified by subjects, the scenes generally representing the worship of the various deities, or sometimes scenes of hunting or war. In the concluding chapters the various ways in which the gods and their emblems are figured have been gathered to the number of about 300 for the easy reference of scholars.

The preparation of this work has occupied the larger part of Dr. Ward's study for five years, and constant attention has been given to the subject since his return from a visit to Babylonia in 1884–85 as director of the Wolfe Expedition. During this period he made the collection of cylinders belonging to the Metropolitan Museum in New York, which is excelled only by those of the British Museum and the Louvre. His object in the work just completed has been to make accessible all knowledge available to the present date in this department of archeology, of which the late M. J. Ménant was the pioneer in his work "Les Pierres Gravées," published nearly 30 years ago.

ASTRONOMY.

Campbell, W. W., Lick Observatory, Mount Hamilton, California. Grants Nos. 421 and 231. (*a*) *Pay of assistants to take part in researches at the Lick Observatory,* $4,000. (*b*) *Measurement and reduction of photographic plates of Eros,* $3,000. (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $7,000.

(*a*) In the spectrographic determination of stellar velocities there have been employed, as assistants in the past year: Miss Leah Allen, October 1, 1907, to October 1, 1908; and Miss A. M. Hobe, July 15, 1908, to October 1, 1908. Miss Allen reduced measures of 257 spectrograms made by Dr. Newkirk in the preceding year, measured and reduced 103 spectrograms, computed the "reductions to the sun" for more than 400 spectrograms secured within the year, checked the reductions to the sun for about 500 spectrograms obtained in previous years, and assisted with the records of current observations.

After acquiring the familiarity and training that is indispensable in taking up this delicate work, Miss Hobe measured and reduced 101 spectrograms, and assisted with several minor computations connected with this subject.

Mr. R. F. Sanford assisted Professor Tucker from October 1, 1907, to July 1, 1908, with the meridian-circle observations and reductions for determining fundamental star positions. Mr. Sanford left the employ of the Observatory in order to serve with Professor Tucker in the work of the Institution at San Luis, Argentina.

(*b*) The Crossley reflector photographs of Eros were under measurement and reduction during five months of the year by Miss A. M. Hobe and Mrs. J. H. Moore. Their duties in this connection were concluded on July 15. Professor Perrine's time in the past year has been devoted in good measure to determining the most probable value of the solar parallax afforded by these photographs. The results of measurement were combined so as to afford two essentially independent solutions as a check against systematic and computational errors. The resulting values of the parallax are 8.806″ and 8.807″. The probable error is ±0.0025″.

The manuscript copy of a proposed volume embodying the essential measures, computed quantities, and results is nearly ready for the printer, but is retained pending a reinvestigation of an apparent periodic inequality in many of the meridian positions of Eros. There are indications that this inequality may be connected in some way with the period of the light variation of Eros, and this possible connection is under consideration.

Newcomb, Simon, Washington, District of Columbia. Grant No. 487. *Investigations in mathematical astronomy, statistical methods, and economic science.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $5,000.

Dr. Newcomb reports the following:

Completion of the Equations of Condition from Occultation of Stars by the Moon from 1672 till the Beginning of 1908. The solution of the equations is in progress, and the discussion of results includes not only the elements of the moon's motion, but other fundamental astronomical constants pertaining to the sun and stars. The long delay in bringing this work to a termination has arisen partly from the necessity of introducing many corrections in the older work and from the inclusion of a great number of additional observations, especially those of recent years. This study shows beyond serious doubt that the motion of the moon is subject to fluctuations for which no known cause is adequate to account.

Corrections to Oppolzer's Tables of Eclipses, with a view of using them in a general rediscussion of ancient eclipses of the sun.

Continuation of the work on the theory of probable inference, as applied to the derivation of results from observations of a statistical character.

Preliminary studies of the perturbations of Mars, with a view to new tables of that planet. It is hoped that this work will be continued under the auspices of the Nautical Almanac Office.

A paper on the "Best form for new tables of the moon" was issued in the Monthly Notices of the Royal Astronomical Society, June, 1908, and an article on the "Investigation of the fluctuations in the temperature of various regions of the earth since 1820" was published by the American Philosophical Society during the past year.

A résumé of the history and present state of the lunar theory was read before the Congress of Mathematicians in Rome in April.

Russell, Henry N., Princeton, New Jersey. Grant No. 207. *Photographic determination of stellar parallaxes.* (For previous reports see Year Books Nos. 3, 5, and 6.) $1,000.

In this work the photographic observations, continued at Cambridge, England, by Mr. A. R. Hinks, have been completed. The whole number of plates used is 258 of 38 different fields; 161 of these were obtained by Dr. Russell and 97 by Mr. Hinks, and all have been measured by Dr. Russell, and the measures completely reduced.

For 31 series observations were obtained at from 3 to 6 parallactic epochs. These series include 220 plates, with a total of 853 exposures, and upon these plates 7,899 images of 287 stars have been measured. The parallaxes

and proper motions of all these stars have been determined. For 44 stars, especially selected for investigation, the computations have been made by least-squares. For the comparison stars, 243 in number, a shorter process, of practically equal accuracy, was employed.

The remaining 7 fields, of which 38 plates were obtained, could be photographed at only two epochs, owing to an accident to the color-screen. These give the parallax of 8 bright stars (the principal objects in these fields), whose proper motions are accurately known from meridian observations, with almost the same accuracy as the other series. The whole number of stars whose parallax has been determined is thus 295.

The general discussion of the results is so far advanced that a summary may here be given of the principal conclusions derived from the data for the 287 stars which form the principal part of the work.

(1) The results strongly support the theories of Newcomb and Kapteyn concerning the distribution of the stars in space. Of the 44 parallax stars (*i. e.*, those especially picked out for investigation, mostly because of large proper motion or some other indication of probable nearness), 31 give positive parallaxes, and only 3 negative ones, which exceed their probable errors, while for the remaining 10 the computed parallaxes are less than their probable errors. It is therefore evident that a large majority of these stars are really nearer us than are the comparison stars, with reference to which their parallax was determined, and that the criteria used in their selection are of real value. Comparison of the individual results with Kapteyn's formulæ for the mean parallax of stars of determined proper motion and magnitude confirms the latter in a very striking manner.

The calculated parallaxes of the comparison stars, on the other hand, are distributed in magnitude in very close accordance with the law of errors. This confirms the conclusions of the above-mentioned astronomers that the differences of parallax of stars of the eighth or ninth magnitude, taken at random, are too small to be detected individually by the present methods of observation.

The computed proper motions of these stars, however, show, in addition to the small errors of observation, unmistakable evidence of real proper motion, whose average amount can be determined with considerable accuracy. The corresponding parallax, on Kapteyn's theory, should be too small to be detected.

(2) The mean parallax of selected groups of the comparison stars may be found with very high accuracy, and in this way much information may be obtained. For example:

(*a*) The means for stars near the center or near the edge of the plate, and also those for stars of different magnitudes, do not differ sensibly.

This shows that there are no systematic errors, affecting the determination of parallax, depending on these things. A very careful search of this sort has failed to detect systematic errors of any sort affecting the parallax by so much as 0.01″.

(*b*) The measured positions are more accurate for stars near the middle of the plate than for those near the edge, and for stars of moderate brightness than for either brighter or fainter ones (whose images are either over- or under-exposed). On the average, the accuracy of the photographs is fully equal to that of any other method of determining the relative positions of stars. Most of the outstanding error is due to real displacements of the star-images on the plate, and can not be eliminated by repeating the measurement. Plates taken at an interval of two years agree practically as well (when allowance is made for the real motion of the stars in the interval) as those taken on consecutive nights.

(*c*) Professor Pickering has very kindly offered to have the spectral types of all the stars observed in this work determined at the Harvard Observatory, and the results for two fields have already been sent to Dr. Russell. It seems probable that the comparison stars are distributed pretty evenly among the different types. The mean parallax of the stars of each type can then be determined with very great accuracy. This will afford the first direct evidence whether red or white stars of the same apparent brightness average nearer to us.

(3) Determinations of the parallax of many of the "parallax stars" of the present work are found among the long series of such observations published since this work was begun. The results of various observers, using different methods, agree, on the average, with those of Dr. Russell within the limits set by the probable errors computed from the "internal" agreement of the observations of each series.

The preparation of a memoir, giving a full account of Dr. Russell's work, is under way, its completion awaiting data which Professor Pickering has kindly offered.

Schlesinger, Frank, Allegheny, Pennsylvania. Grant No. 422. *Completion of parallax computations begun under the direction of Dr. G. E. Hale.* (For previous report see Year Book No. 6, p. 175.) $300.

This work has been somewhat delayed by the pressure of Dr. Schlesinger's other duties, but it is now ready for publication. The parallaxes of 23 stars have been deduced. In some cases it was possible to deduce independent values of the parallax for the same star. A comparison among these, and also with the best previous determinations for some of these stars, indicates that the experiment of determining parallaxes photographically with a long-focus telescope has been very successful. The results of this research are to be published in the Astrophysical Journal.

BIBLIOGRAPHY.

Eames, Wilberforce, Lenox Library, New York, New York. Grant No. 343. *Completion of Sabin's "Dictionary of Books Relating to America," from "Smith to Z."* (For previous reports see Year Books Nos. 5 and 6.) $3,600.

Mr. Eames reports that the material for the completion of the Dictionary of Books Relating to America has now been put into satisfactory shape for the printer, and it is expected that the work of publication will shortly be commenced.

Fletcher, Robert, Army Medical Museum, Washington, District of Columbia. Grant No. 484. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $12,500.

The volume of the Index Medicus for 1907 bears evidence of the continued growth of medical literature throughout the world. The index to the volume, containing names and subjects alone, occupies 204 pages in double and triple columns. A noticeable feature is the vast number of contributions in that and in the current volume on the subject of tuberculosis. The originals of all these references are filed in the Library of the Surgeon-General's Office.

BOTANY.

Burbank, Luther, Santa Rosa, California. Grant No. 483. *Experiments in plant development.* (For previous reports see Year Books Nos. 4, 5, and 6.) $10,000.

Experiments on Mr. Burbank's plantation have been carried on with vigor and have been greatly increased in extent. The work on the cactus has interested numerous foreign governments and some of them are now growing the new cacti lately developed on Mr. Burbank's grounds. These plants are grown without care, culture, or fertilizer, and on hard dry ground, without water, yet the average 3-year-old plant yields over 50 pounds of delicious fruit. The work is well advanced toward making a more hardy species and thus extending the culture to colder quarters of the globe. Mr. Burbank also hopes to bring about a still further productiveness in the cacti, as well as a better chemical composition for the plant, and fruit of various colors, flavors, sizes, and seasons.

A new series of thornless blackberries, with unique qualities, has been developed and many improvements have been made in plums, prunes,

peaches, nectarines, apricots, quinces, plumcots, cherries, raspberries, and numerous other fruits. New forage plants, new roses, bulbous plants, ornamental, nut, and forest trees, and field crops have been grown, and several collectors are employed in securing seeds of wild plants from remote sections of the earth.

CHEMISTRY.

Acree, S. F., Johns Hopkins University, Baltimore, Maryland. Grant No. 498. *A study of tautomerism and catalysis by the use of physico-organic methods.* (For previous reports see Year Books Nos. 4 and 6.). $500.

Professor Acree submits the following abstracts of several articles on investigations carried out with the aid of grants from the Institution:

Ueber die Reactionen tautomerer Saeuren und Salze mit Diazomethan und Alkylhaloiden. (Berichte der deutschen chemischen Gesellschaft, *41*, 3199–3236.)—This article is a short abstract of the quantitative work on tautomerism accomplished during the past three years under the direction of Professor Acree. A full account of the work will appear later as a monograph when several phases of the problem now under way are completed. The theory which was presented tentatively (Year Book, No. 6, p. 178) to account for the phenomena of tautomerism in the urazole series may be stated as follows: The urazole, or its salt, reacts with an alkyl halide, or other reagent, and forms two or more derivatives in constant ratio, because the tautomeric urazole, or its salt, is really a mixture of two or more tautomeric acids, or salts, in constant equilibrium, each tautomeric form of which reacts with the alkyl halide or other reagent in independent side reactions. This theory has been very useful to us in the prediction of all the quantitative facts known at present, and in opening up new lines of research. With the necessary modifications it has been applied to the reactions of many other important classes of tautomeric compounds, such as the phenolphthalein series, acetoacetic ester series, etc.

The following quantitative relations have been predicted and verified experimentally: (1) The equilibrium is between the molecular forms of the urazole salts and not between the anions. The alkyl halide reacts with the anion and yields a complex anion which decomposes into the ester and a halide ion. (2) Different salts have different equilibrium constants and yield with a given alkyl halide different ratios of isomeric esters. Different salts, since they are dissociated to different degrees, react with different velocities with the same alkyl halide. (3) The equilibrium constant of the salt and the ratio of the stable isomeric esters do not change appreciably with a change in temperature. (4) A change in the solvent produces a

change in the ratio of the isomeric esters. (5) Different alkyl halides and the same salt have different reaction velocities and yield different ratios of isomeric esters. (6) Changes in concentration of the two reacting substances produce no appreciable change in the ratio of the isomeric esters. (7) The addition of salts which give ions identical with those present in the reaction mixture produces similar changes in the velocities of the reactions of the two tautomeric salts with the alkyl halide and therefore causes no appreciable change in the ratio of the isomeric esters. (8) Mercury salts of 1-phenyl-4-methylurazole and alkyl halides yield both N-esters and O-esters.

On the Velocity Constants and Mechanism of the Reactions of Alkyl Halides with Urazoles and Urazole Salts. (American Chemical Journal, *39*, 226–277.)—This article contains part of the work accomplished in the quantitative study of the mechanism of reactions of alkyl halides, sulphates, acid chlorides, mustard oils, isocyanates, etc., with salts, acids, bases, alcohols, amines, etc. Especial attention is being given to those cases in which both esters and olefines are formed in considerable amounts.

The results obtained up to this time indicate that the alkyl halides do not react (1) through primary dissociation into alkyl and halide ions (theory of Bruyn and Steger); (2) through primary dissociation into a halogen acid and an unsaturated olefine or alkylidene residue (theory of Nef); nor (3) through the primary union of the alkyl halide with the cation and the formation of a complex cation, $RI.M.^{+}$, which then reacts with the anion (theory of Euler). The evidence at hand seems to prove that the alkyl halide unites with the anion and forms a complex unstable anion which decomposes into the ester and the halide ion. In some cases this complex anion is present in small amounts which are very reactive; in other cases, which are occupying at present our special attention, the concentration of the complex anion is comparatively large. The nature of the reactions by which the olefines are formed is being especially investigated; the evidence secured up to this time shows that they are formed through a reaction which is independent of that by which the ester is obtained.

On the Theory of Indicators and the Reactions of Phthaleins and their Salts. (American Chemical Journal, *39*, 528–544; *39*, 789–791.)—A problem of great practical and theoretical importance engaging our attention is the study of the cause of color in dyestuffs and indicators. In these two articles it has been shown that the theory proposed by Nietzki, Friedlaender, and Baeyer, and adopted by Hantzsch, Kauffmann, Stieglitz, and others, that the quinone group, B, is the sole source of the color in the salts of phenolphthalein, rosaniline, etc., is not entirely in harmony with the facts.

$$(NaOC_6H_4)_2CC_6H_4COO \rightleftharpoons (NaOC_6H_4)(O{:}C_6H_4{:})CC_6H_4COONa \rightleftharpoons$$

A. Colorless. B. Somewhat colored.

$$(NaOC_6H_4)(O{:}C_6H_4{:})CC_6H_4COONa$$

C. Deeply colored.

$$[(CH_3)_2NC_6H_4][\overline{Cl}(CH_3)_2\overset{+}{N}{:}C_6H_4{:}]CC_6H_4N(CH_3)_2 \rightleftharpoons$$

B. Somewhat colored.

$$[(CH_3)_2NC_6H_4][Cl(CH_3)_2N{:}C_6H_4{:}]CC_6H_4N(CH_3)_2$$

C. Deeply colored.

We have found that the theory of tautomeric salts is entirely adequate to make clear the constitution of the colored and colorless salts as well as the formation of isomeric esters in the alkylation reactions of the acids and salts. We have secured evidence which shows that in solutions of the salts of phenolphthalein and analogous compounds at least three tautomeric salts, A, B, and C, exist in equilibrium with each other and their ions. A is colorless, B is somewhat colored, and C, an intra- or inter-molecular compound of the quinone and phenolate groups which we call a *quinone phenolate* compound, is deeply colored. Each salt reacts with alkyl halides and forms the corresponding colorless and colored esters, those corresponding to C probably changing into those corresponding to B, and these sometimes changing into those of the form A. Likewise the salts of rosaniline, and similar compounds, exist in solution in the two tautomeric forms B and C. C, which we call a *quinaminone,* is far more deeply colored than A. Colorless salts of the phenolphthalein series corresponding to A are known in the salts of para-oxydiphenylphthalid, the phenol methyl ester of phenolphthalein, the phenol ethyl ester of tetrabromphenolphthalein, the anilides of phenolphthalein and hydroquinonephthalein, etc. These yield with alkyl halides only the phenol esters, as is to be expected. But the colored salt of the phenol ethyl ester of fluorescein, which becomes in solution a mixture of the three salts corresponding to E and F and the *quinone phenolate* formed by the union of these, yields with alkyl halides a mixture of the corresponding colorless and colored phenol and carboxyl esters.

$$(CH_3OC_6H_4)(NaOC_6H_4)CC_6H_4COO \rightleftharpoons (CH_3OC_6H_4)(O{:}C_6H_4{:})CC_6H_4COONa$$

E. Colorless. F. Somewhat colored.

The chief source of color in dyestuffs (both basic and acid) is not the quinone group, but one or more inter- or intra-molecular reversible combina-

tions of a quinone group with a salt of a phenol, or with an aniline-like group, and the mechanical change from one to the other, or a corresponding movement of electrons, is very probably connected with the color changes. A small amount of color is, of course, due to the quinone group.

Studies in Catalysis: (1) *On the Hydrolysis of Amides by Acids.* (American Chemical Journal, *38,* 489–507.) (2) *On the Reactions of Carbonyl Compounds with Hydroxylamine and Hydroxylamine Hydrochloride.* (American Chemical Journal, *39,* 300–309.)

(1) In the first of these articles is the report of a quantitative study of the hydrolysis of acetamide by hydrochloric acid. The experimental and mathematical evidence shows clearly that neither the amide nor the undissociated amide hydrochloride is readily decomposed, but that the amide cation, $CH_3CO\overset{+}{N}H_3$, is the chief substance hydrolyzed. Similar reactions take place in the saponification of esters and amides by alkalies.

$$RCO\overset{+}{N}H_3 + H_2O(\text{or } \overset{+}{H} + \overline{O}H) \longrightarrow RC(OH)_2\overset{+}{N}H_3 \longrightarrow RCOOH + \overset{+}{N}H_4$$

$$RCONH_2 + \overset{+}{K} + \overline{O}H \longrightarrow RC\overline{O}(OH)NH_2 + \overset{+}{K} \longrightarrow RC\overline{O}O + \overset{+}{K} + NH_3$$

This theory enables us to predict that other substances, such as alcohols, mercaptans, hydroxylamine, etc., should also react with the amide cation. Dr. E. E. Reid has been able to show that excellent yields of esters may be formed from alcohols and amides, anilides, and hydrazides in the presence of acids. It was found that certain salts accelerate these catalytic reactions while other salts retard them: the cause of this salt catalysis is being investigated. We are making a study of the reverse reactions, the formation of amides, anilides and hydrazides from the esters, or acids, and ammonia, amines, hydrazines, etc.

$$CH_3COOR + NH_3(\text{or } \overset{+}{H} + \overline{N}H_2 \text{ or } \overset{+}{N}H_4 + \overline{N}H_2) \longrightarrow CH_3CONH_2 + ROH.$$

(2) In the study of the reactions of carbonyl compounds with hydroxylamine and its salts it has been established that the reaction between free hydroxylamine and acetone proceeds nearly to completion with a velocity which, though somewhat slow, is readily measured. When acids are added this reaction velocity is very greatly increased and the process, instead of going to completion, shows itself to be reversible, the equilibrium point depending upon the amount of acid added. This is the first experimental disproof of the so-called law of catalysis postulating that the equilibrium point of a catalyzed reaction does not vary with a change in the concentration of the catalyzer.

The reactions may be briefly written:

$$(CH_3)_2CO + NH_2OH \text{ [or } \overset{+}{H} + \overline{N}HOH \text{ or } \overline{N}HOH(NH_2\overline{O}) + \overset{+}{N}H_3OH] \rightleftharpoons (CH_3)_2C=NOH + H_2O;$$

$$(CH_3)_2CO + NH_2OH + \overset{+}{H} + \overline{Cl} \rightleftharpoons (CH_3)_2C\overset{+}{O}H + \overline{Cl} + NH_2OH \text{ (or as above)} \rightleftharpoons$$

$$(CH_3)_2C=\overset{+}{N}HOH + Cl + H_2O \rightleftharpoons (CH_3)_2C=NOH + \overset{+}{H} + \overline{Cl} + H_2O, \text{ etc.}$$

When alkalies are added to the acetone and hydroxylamine the reaction is very greatly accelerated and goes nearly, or quite, to completion. We are studying this very important reaction with the idea of clearing up a number of other points.

Dr. J. M. Johnson, Dr. R. F. Brunel, Dr. G. H. Shadinger, Dr. F. M. Rogers, Dr. E. E. Reid, and Messrs. Desha, Nirdlinger and Slagle have collaborated in the above investigations.

Bancroft, Wilder D., Cornell University, Ithaca, New York. Grant No. 411. *Systematic study of alloys.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $1,000.

The results of experiments on the electrolytic corrosion of copper-aluminum alloys have been published in the Journal of Physical Chemistry, volume 12, page 180 (1908). The different phases show marked differences as to corrosion in presence of different salts; but so far no satisfactory theory has been devised. The results demonstrate anew the utter futility of electromotive-force measurements as a means of predicting chemical corrosion. The problem is really one of the formation and properties of surface films.

During the past year most of the time has been spent on the iron-carbon alloys. A satisfactory modification of the General Electric Company's vacuum furnace has enabled Dr. Bancroft to melt and then to chill-cast the alloys in a vacuum. In this way samples have been obtained containing up to 6 per cent carbon which show no free graphite. These samples have been annealed in a vacuum at 1,000° for periods of 100 hours and over. Under these circumstances equilibrium is reached; but it has not been possible to quench the alloy sufficiently rapidly to prevent the crystalline structure from changing to such an extent that no conclusions could safely be drawn from a microscopic investigation. Dr. Bancroft is now planning to determine heating curves in a vacuum. It has been proved that precipitated graphite is reabsorbed and that ferrite and graphite are not the stable forms, as has been claimed by Heyn. Mr. G. B. Upton has put forward a tentative diagram which appears to account for all the experimental facts known so far.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. Grant No. 451. *Researches upon atomic weights.* (For previous reports see Year Books Nos. 3, 4, 5, and 6.) $1,000.

The analysis of iodine pentoxide, commenced by Mr. G. S. Tilley, has been continued by Professor Baxter. Iodic acid, made by the action of pure fuming nitric acid upon the purest iodine in vessels of fused quartz, was purified by crystallization in quartz vessels. Portions of about 10 grams of the acid were carefully dehydrated in a platinum boat in a current of dry air, the temperature finally reaching 240° C., and the resulting iodine pentoxide was weighed. Then it was dissolved in water, reduced in dilute nitric acid solution by means of hydrazine, and finally it was precipitated in about thirtieth normal solution with a nitric-acid solution of a weighed amount of silver, a very few tenths of a milligram in excess of the necessary quantity being used. This excess of silver was determined gravimetrically after evaporation of the entire filtrate to small volume. It was found impossible to use sulphurous acid as the reducing agent, owing to occlusion of silver sulphate. The ratio of silver to iodine pentoxide was found in seven experiments to be 0.646212. Assuming the iodine pentoxide to have been pure and using the ratio of silver to iodine already determined by Baxter, 0.848843, the atomic weight of silver referred to oxygen 16.000 is calculated to be 107.837, which is undoubtedly a minimum value.

However, the iodine pentoxide was found to contain traces of moisture, and during the present year the water content of the pentoxide after drying at 240° was first thoroughly investigated. Weighed quantities of the pentoxide were decomposed by heating in a current of dry air, and, after removal of iodine by condensation and then by a layer of hot silver, the water was collected in a phosphorus pentoxide tube and weighed. The water content of the iodine pentoxide was found to vary only slightly when the conditions of heating the substance were somewhat varied, and was constant at 0.023 per cent. when the pentoxide was heated as in the analyses for iodine. If a correction for this moisture is applied, the atomic weight of silver becomes 107.847.

The possibility of the adsorption of air upon the surface of so porous a material as iodine pentoxide which has been made by efflorescence of iodic acid led to experiments to test this point. From the gain in weight when air was admitted to an exhausted tube containing iodine pentoxide, the density of the pentoxide was found to be almost exactly that found by displacement of toluol. If the pentoxide adsorbs air, a lower density is to be expected when determined by displacement of toluol.

Finally, a second series of analyses of iodine pentoxide by titration against silver were carried out, with new samples both of iodic acid and of silver.

The conditions of precipitation were varied without appreciable effect. No evidence of occlusion of either iodide or silver salts could be detected. The results of these analyses confirm with great exactness the first series of determinations, ten analyses giving an average ratio of silver to iodine pentoxide of 0.646217, with an extreme difference of only 0.002 per cent. From this ratio, after correction for the impurity of water, the atomic weight of silver referred to oxygen is calculated to be 107.850.

This value is lower than is to be expected and the problem is being further investigated. The preliminary results of the research are now in process of publication in the Journal of the American Chemical Society and in the Zeitschrift für anorganische Chemie.

Mr. R. H. Jesse, Jr., has continued the investigation upon the atomic weight of chromium, by analysis of silver dichromate. This salt was prepared from pure silver nitrate and either purified potassic dichromate or chromic anhydride, and was crystallized from nitric acid of different concentrations. It was dried by being heated to 200° C. for some time in a current of dry air. The silver content of the salt was found, after solution in dilute nitric acid and reduction with sulphurous acid, by precipitation as silver bromide or chloride. The salt, after being dried as above, was found to contain traces of both nitric acid and water, which were expelled from weighed quantities of the salt by fusion in a current of dry air, and were collected in weighed tubes containing caustic potash and phosphorus pentoxide. The correction thus obtained varied only slightly with the concentration of the acid from which the salt was crystallized.

The analyses of the different samples of material, after correction for the water and nitric acid, yielded the following results, upon the assumption that the atomic weight of silver is 107.88:

Concentration of nitric acid.	No. of analyses.	Atomic weight of chromium.
Per cent.		
1	4	52.009
5	3	52.019
20	2	52.013
Average..	.....	52.014

The analysis of silver chromate by Dr. Mueller indicated the value 52.01 for the atomic weight of chromium, a highly satisfactory agreement. The two investigations upon silver chromate and silver dichromate are being published in the Proceedings of the American Academy of Arts and Sciences.

The analysis of silver arsenate, begun last year by F. B. Coffin, has been completed. In this research silver arsenate, prepared by precipitation, was

washed and dried at 250° in a current of dry air. Then after being weighed, it was analyzed, either by heating in a quartz tube in a current of pure hydrochloric-acid gas until all arsenic had been expelled, or by solution in nitric acid and precipitation with either hydrochloric or hydrobromic acid. All three methods gave essentially the same results. A slight amount of residue insoluble in dilute nitric acid was found to have essentially the same proportion of silver as the arsenate itself. Since the residue was dissolved in more concentrated acid before precipitation of the silver halides, no correction for the residue is necessary. The proportion of water in the dried salt was found by fusing weighed amounts of the salt in a current of dry air and collecting the water set free in a weighed phosphorus pentoxide tube. After applying a small correction found by blank experiments with the apparatus, the proportion of water was determined to be 0.0056 per cent. Silver arsenate made from tri-sodic arsenate contains a slightly higher percentage of silver than material made from other di- and tri-arsenates of sodium and ammonium. On account of the distinctly basic nature of tri-sodic arsenate, it is probable that the silver salt made from it contains basic impurity. Hence the results from this material were not considered of value and are omitted in the following table. Silver is assumed to have the atomic weight 107.88.

Sample.	Source of silver arsenate.	No. of analyses.	Average atomic weight of arsenic.
A	$Na_2(NH_4)AsO_4$	3	74.960
B.....	Na_2HAsO_4.....	1	74.956
C	Na_2HAsO_4.....	3	74.959
D	$(NH_4)_3AsO_4$	4	74.952
E	Na_2HAsO_4.....	3	74.956
Average	.....	.....	74.957

The results of this investigation are being published in the Proceedings of the American Academy of Arts and Sciences. Work is under way on the ratio of arsenic trioxide to iodine and iodine pentoxide.

It has not been possible to complete the analysis of silver phosphate which was begun last year by Dr. Grinnell Jones. This investigation will, however, be continued in the near future. The atomic weight of phosphorus was further investigated by Mr. A. C. Boylston, who undertook first the analysis of phosphonium bromide. This substance, owing to its unstable nature, was found unsuitable for exact work. Phosphorus tribromide was next selected for investigation and a method for preparing the tribromide in a pure state in the absence of moisture was devised. Unfortunately the serious illness of Mr. Boylston interrupted this research before any conclusive analytical results had been obtained. This investigation will be continued during the coming year.

An investigation upon the atomic weight of neodymium has been begun by Mr. H. C. Chapin. Through the kindness of the Welsbach Light Company over 5 kilograms of neodymium ammonium nitrate were available as a starting-point. Since it is not possible to separate completely a substance from a less soluble isomorphous impurity by crystallization, search was first made for two solvents such that the impurities which tend to concentrate in the crystals separating from one solvent concentrate in the mother-liquors of the other. This is the case in the crystallization of the double ammonium nitrate from dilute nitric acid, and of the nitrate from concentrated nitric acid. In crystallizing the double ammonium nitrates from dilute nitric acid, lanthanum and praseodymium concentrate in the extreme crystal end, while samarium and gadolinium concentrate in the mother-liquors. Exactly the reverse is true when the nitrates are crystallized from concentrated nitric acid. Many thousand crystallizations have been carried out with some of the material, and some very pure specimens have been prepared. Comparison of the various samples of material will be made by analysis of the chloride. None have as yet been completed.

Goldthwait, Joel E., Boston, Massachusetts. Grant No. 468. *For the chemical study of the ætiology of the so-called "rheumatoid diseases."* $2,000.

The object of this grant was to aid in ascertaining the precise chemical nature of the toxins generated by bacteria now known to be one of the principal causes of rheumatoid disorders, with the idea that assistance for bacteriological investigations allied with the study should be obtained from other sources.

Dr. H. W. Marshall, who has had immediate charge of the work, reports that during the past year investigations have been started upon the subject of chronic non-tubercular arthritis, which must necessarily continue for a considerable period of time before sufficient data can be accumulated to make any authoritative statements possible, but enough has been accomplished to indicate definitely the line of investigation in the future. The class of cases about which the work has centered up to the present time have been those obscure chronic types called rheumatoid arthritis, leaving out of consideration undoubted cases of infectious origin, like gonorrheal arthritis and traumatic varieties, or those due to mechanical irritation simply, also the neuropathic kinds represented by Charcot's joints. Clinical material has been obtained from the Massachusetts General Hospital and also from Dr. Goldthwait's private practice.

While no positive results have been obtained from the work of the year, at the same time data of extreme suggestiveness have developed which promise much in the ultimate solution of the problem. Because of the

progress of the work and of the suggestive elements which have developed, Dr. Otto Folin and Dr. Theobald Smith, both of the Harvard Medical School, have consented to associate themselves with the future course of the investigation. Dr. Charles G. Weld, of Boston, has also generously put the investigation upon a satisfactory financial basis.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. Grant No. 499. *Investigation on the absorption spectra of solutions—a continuation of the work on hydration in aqueous solutions and solvation in solutions in general.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $800.

This investigation on the absorption spectra of solutions, carried out with the assistance of Dr. John A. Anderson, is an extension of the work of Jones and Uhler on absorption spectra, published by the Carnegie Institution of Washington as part of publication No. 60.

A number of problems in connection with the absorption of light by dissolved substances were taken up in this work. The effect on absorption of keeping constant the total amount of coloring matter in the path of the beam of light, but varying the concentration of the solutions, aqueous and non-aqueous, was pretty thoroughly studied. The effect of keeping constant the total number of molecules in the path of the beam of light, and allowing the number of the ions to vary was also carefully investigated.

Such dehydrating agents as calcium chloride and aluminium chloride were added to the aqueous solutions of colored chlorides, and the resulting absorption spectrum photographed.

The addition of water to the solutions in non-aqueous solvents was carefully studied, and interesting results were obtained in this field. The salts brought within the scope of this investigation are the chloride, bromide, nitrate, sulphate, sulphocyanate, and acetate of cobalt; the chloride, sulphate, and acetate of nickel; the chloride, bromide, and nitrate of copper; the chloride of iron; the chloride and nitrate of chromium; the chloride, bromide, and nitrate of neodymium; the chloride and nitrate of praseodymium; and the chloride and nitrate of erbium.

The method of making the spectrograms, and the cells employed for holding the solutions, were essentially the same as had been used by Jones and Uhler. The electrodes for obtaining the spark were, however, quite different. Instead of passing the spark between electrodes of zinc-cadmium, it was found that much better results could be obtained by using carbon electrodes which had been dipped into a solution of ammonium molybdate, heated, then into a solution of uranium nitrate and again heated.

The results obtained with the 1,200 solutions studied will soon appear as publication No. 110 of the Carnegie Institution of Washington. A few of the facts established and the conclusions reached can, however, be given here.

Beer's law says that when the total amount of coloring matter in the path of the light remains constant the absorption should be constant independent of the concentration. The exceptions to this law are very numerous, only a few salts conforming to it. This is exactly what should be expected in terms of Jones's hydrate theory, since solutions almost always contain more than one kind of "absorber," and the relative proportions of these would continually change with change in concentration. Beer's law could hold only when the relative concentrations of the different kinds of absorption did not change. The theory of Ostwald, which refers absorption in solution mainly to the ions, is insufficient to account for the deviations from Beer's law.

The other two theories of absorption in solution are: (1) That the increased absorption in concentrated solution is due to the formation of aggregates of the molecules of the dissolved substance, or of the molecules and the resulting ions; (2) that absorption is largely referred to the formation of solvates, *i. e.,* combination of the dissolved substance with the molecules of the solvent.

It has been shown that those bands that widen with increase in concentration also widen with rise in temperature—rise in temperature producing very much the same effect as increase in concentration. Rise in temperature renders aggregates simpler, while increase in concentration makes them more complex, and this argues against the association theory as an explanation of the well-established facts in connection with absorption in solution.

These facts are, however, in perfect accord with the *solvate theory of absorption,* since both rise in temperature and increase in concentration produce the same effect on solvates—rendering them simpler.

Some of the most interesting and important results were obtained with salts of neodymium and praseodymium. These salts have not only a large number of absorption bands, but they are unusually narrow and sharp, especially for the neodymium compounds.

The absorption spectra of aqueous solutions of the chloride and bromide of neodymium are nearly identical, and change very little with change in concentration. These facts can not be accounted for on the ionic theory of absorption. The absorption spectrum of the nitrate is also somewhat different from that of the chloride and bromide. It was found that the addition of large amounts of calcium or aluminium chloride to a solution of neodymium chloride does not appreciably affect the spectrum.

Solutions of the salts in non-aqueous solvents give spectra which are not only different for the different salts, but the spectrum of any one salt is different in one solvent from what it is in any other solvent.

One of the most important facts brought out in this work is the following: When a salt like neodymium chloride is dissolved in mixtures of water and one of the non-aqueous solvents, and the relative amounts of the two solvents

in the mixture are varied, no marked change in the spectrum is observed when the amount of water is varied from 100 per cent to about 15 or 20 per cent. As the amount of water is still further reduced we find that the solution gives a spectrum which consists of a superposition of the spectra belonging to the aqueous and the non-aqueous solutions, the former decreasing in intensity, while the latter increases, as the amount of water is decreased. The composition of the mixed solvent which will show the two spectra with about one-half their normal intensity depends upon the concentration of the salt in solution; and a constant ratio between the number of molecules of water and those of the dissolved salt was indicated by the experiments, this ratio having the value ten.

Neodymium nitrate dissolved in mixtures of water and one of the non-aqueous solvents shows exactly the same change as the chloride, but there are also shown the changes in the spectrum produced by the great change in the state of dissociation of the salt. The result is that the whole change is a much more gradual one, and hence is not nearly so striking as it is in the chloride or bromide solutions.

Praseodymium chloride dissolved in mixtures of water and methyl or ethyl alcohol shows in general the same kind of change in the spectrum as neodymium chloride; but in addition there appears in the alcoholic solutions an entirely new band having no analogue in the aqueous solution. In the former this new band in the ultra-violet is by far the most intense in the entire spectrum. It disappears entirely on addition of water, having about half its normal intensity for a half-normal solution when the water content of the solvent is about 8 per cent.

The points emphasized most strongly are, then:

(1) That the absorption spectra of different salts of the same metal in the same solvent are different if the concentration is great, or, more generally, if the dissociation is only slight; and that as the dissociation becomes more and more complete, they become more and more alike.

(2) That the absorption spectra of the same salt in different solvents are in general different.

(3) That with change in dissociation of the salt in any one solvent, the change in the absorption spectrum of salts having anions containing only a few atoms, such as the chloride and bromide, is very slight, but that as the complexity of the anion increases the change becomes more and more pronounced.

(4) That when a salt is dissolved in mixtures of two solvents, the relative percentages of which are varied, there is not a gradual change of one spectrum into the other; but the spectrum given by the mixture is a superposition of the two spectra, the two sets of bands existing together. If the salt is one whose spectrum changes considerably with its state of dissociation, we have

in addition to the above phenomena the changes due to the varying dissociation of the dissolved salt produced by the varying composition of the mixtures.

These facts seem inexplicable on any other hypothesis than the one used, namely, that when a salt of one of these elements is dissolved in any solvent, *both the molecules of the salt and the ions formed from them become solvated; that is, they combine with a certain number of molecules of the solvent.*

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. Grant No. 500. *The measurement of osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $1,800.

The principal work of the past year has been in two directions—first, in that of bettering the apparatus and methods, and second, in that of measuring pressure under the improved conditions, the ultimate purpose being to secure, if possible, reliable evidence regarding the temperature coefficient of osmotic pressure.

The complex and difficult procedure of determining osmotic pressure had previously been developed to a point where the results obtained were undoubtedly approximately correct, but yet not sufficiently precise to reveal with certainty the exact relation of the force to temperature. There were, in general, three principal sources of error in the method which have been combated from the first, but which it was necessary to bring under still better control before the object in view could be secured.

There were, in the first place, a number of probable sources of error of appreciable magnitude connected with the manometric portion of the work. To eliminate these, an apparatus was devised which, in addition to increasing the convenience and accuracy of calibration, made it possible to test and compare the calibrated manometers under all pressures between 1 and 300 atmospheres. A new and more satisfactory apparatus for filling and finally closing manometers was also devised; and the instruments were filled with nitrogen instead of air, it having been observed that, however great the pains taken to purify the mercury, there is an apparent slow decrease in the volume of the gas when manometers filled with air are employed. An account of this work has been given in a paper which appeared in the October number of the American Chemical Journal.

The largest errors in the more recent measurements of osmotic pressure have been due to a dilution of the cell contents which resulted from the sucking in of water from the wall while the cell was being closed at the beginning and opened at the end of an experiment. With optically active substances, like the sugars, it was easy to determine the total amount of dilution; but, in order properly to correct for it, it was necessary to know what proportion of the whole dilution occurred at each period, since dilution occurring during the

closing period precedes the measurement of pressure, while that which occurs at the end of the experiment is subsequent to the measurement and is to be neglected. No sure means of discriminating between the two had been discovered and the resulting uncertainties were sufficient to mask the effect of temperature upon pressure. It was highly desirable, therefore, to suppress all dilution, or at least to reduce it to an insignificant minimum. This has been accomplished by making radical changes in the construction of the porous cells and their attachments. The work along this line has been described in the September number of the American Chemical Journal.

The third large source of error in the measurement of osmotic pressure was due to fluctuations in the temperature of the bath. Such changes during an experiment produce the so-called *thermometer effects* which have been much discussed in the various papers already published. It is sufficient for the present purpose to state that a rising temperature in the bath produces an overpressure in the cell, while a falling temperature has the opposite effect, and that these changes, unless they are very minute and exceedingly slow, may lead to errors large enough to make the determination of a temperature coefficient impossible. The older arrangements for temperature regulation were found to be quite inadequate and entirely new ones were devised, which enable us to secure and automatically maintain for any length of time any temperature between that of the hydrant water and 50°. The unavoidable fluctuations do not exceed 0.1° in the largest baths. A paper in which the new arrangements are described is in process of preparation.

Briefly stated, the system consists in rapidly passing the water in a bath first over a cooled surface and then over a heated one. The former is secured by the regulated flow of hydrant water through coils of pipe, or a closed chamber, which is submerged in the bath. If necessary, as when a low temperature is to be maintained in hot weather, the hydrant water is previously cooled by passing it through pipes lying in ice water. The heating of the second surface is electrical, and is under the control of a thermostat immersed in the water of the bath. The flow of hydrant water is so regulated that it would normally maintain in the bath a temperature somewhat below that required, while the heating arrangement is capable of carrying it considerably higher. It will be seen that, under these conditions, any temperature for which the thermostat is set will be automatically maintained, the exactness of the regulation depending solely on the sensitiveness of the thermostat. When temperatures above that of the air are to be maintained, the flow of the hydrant water is cut off. The exterior of the bath then becomes the cooled surface and the regulation of temperature proceeds without change in principle. The system has been found to be generally applicable to bath control in the laboratory.

Three series of measurements of osmotic pressure were carried out under the improved conditions just outlined, and a fourth one is nearly finished. It is believed that the errors in these determinations are limited to the second decimal place in the numbers expressing the observed pressures, which is a degree of accuracy hitherto unattainable. The effect of this increase in precision is observable in the temperature coefficient of osmotic pressure which is brought to light by the recent work.

One series of measurements at 10° was made with glucose solutions, which varied by tenths from 0.1 to 1.0 weight-normal concentration. A summary of the results is given in the following table:

Summary of Results—Mean Values.

Concentration.	Temperature.	Loss in rotation.	Correction for dilution.	Osmotic pressure.	Gas pressure.	Difference.	Molecular osmotic pressure.	Molecular gas pressure.	Ratio of osmotic to gas pressure.
	°	°							
0.1	10.15	0.03	0.01	2.39	2.31	0.08	23.87	23.10	1.035
0.2	10.30	0.00	0.00	4.76	4.62	0.14	23.80	23.10	1.030
0.3	10.00	0.00	0.00	7.11	6.92	0.19	23.70	23.07	1.027
0.4	10.10	0.00	0.00	9.52	9.24	0.28	23.80	23.10	1.030
0.5	10.15	0.00	0.00	11.91	11.55	0.36	23.82	23.10	1.031
0.6	10.05	0.00	0.00	14.31	13.85	0.46	23.84	23.08	1.033
0.7	10.00	0.10	0.05	16.70	16.16	0.54	23.85	23.09	1.033
0.8	10.00	0.05	0.03	19.05	18.46	0.59	23.81	23.08	1.032
0.9	10.05	0.18	0.09	21.39	20.78	0.61	23.74	23.09	1.030
1.0	10.00	0.18	0.09	23.80	23.08	0.72	23.80	23.08	1.031
							23.80	23.09	1.031

The definite conclusions to be drawn from the table are: (1) that, at 10°, as had previously been found at other temperatures, the osmotic pressure of glucose solutions is strictly proportional to their weight-normal concentration; (2) that, at this temperature, the osmotic pressure of glucose solutions exceeds gas pressure by 3 per cent, as will be seen in the column under "Ratio of osmotic to gas pressure." At 0° the excess of osmotic over gas pressure had been found to be about 5 per cent, but this value will be somewhat changed when the work at 0° is repeated under the recently improved conditions.

If the results at 10° are compared with the earlier but less reliable ones at 0°, the existence of a decided temperature coefficient is discernible, but it would be premature to discuss its magnitude until the work at 0° has been repeated and the pressures at still other temperatures have been determined. As soon as practicable, series of measurements at 0°, 5°, 15°, 20°, 25°, and 30° will be carried out. An account of the work upon glucose solutions at 10° will be found in the July number of the American Chemical Journal.

Two series of measurements, one at 10° and the other at 15°, were made with cane-sugar solutions, the concentrations being the same as in the case of glucose. A table is appended in which are given a summary of the results at 10° and 15°, and also, for purposes of comparison, those which had previously been obtained at 0° and in the vicinity of 5°.

Concentration.	Series III pressures (0°).	Series IV pressures (4° to 5°).	Series V pressures (10°).	Series VI pressures (15°).
0.1	2.42	2.40	2.44	2.48
0.2	4.79	4.75	4.82	4.91
0.3	7.11	7.07	7.19	7.33
0.4	9.35	9.43	9.58	9.78
0.5	11.75	11.82	12.00	12.29
0.6	14.12	14.43	14.54	14.86
0.7	16.68	16.79	17.09	17.39
0.8	19.15	19.31	19.75	20.09
0.9	21.89	22.15	22.28	22.94
1.0	24.45	24.53	25.06	25.42
(*a*) Total pressures	131.71	132.68	134.75	137.49
(*b*) Mean molecular osmotic pressures	23.95	24.12	24.50	24.98
(*c*) Mean molecular gas pressures	22.29	22.65	23.09	23.50
(*d*) Mean ratio of osmotic to gas pressure	1.074	1.065	1.061	1.064

To facilitate a comparison of the results presented in the table, there are given: (1) the total number of atmospheres of pressure which were measured in each series (horizontal line *a*); (2) the mean molecular osmotic pressure in atmospheres (horizontal line *b*); (3) the corresponding molecular gas pressures (horizontal line *c*); (4) the ratio of the osmotic pressures found to the calculated gas pressures at the same temperatures (horizontal line *d*). No extended discussion of the data presented can be entered upon in this report, but it will be noted that there is a continuous increase in pressure with rising temperature (lines *a* and *b*), indicating the existence of a temperature coefficient; also that the osmotic pressure is steadily in excess of gas pressure (lines *b* and *c*.) The most important conclusion to be deduced from the results is arrived at when osmotic is compared with gas pressure at the different temperatures (line *d*). Except in the case of the series at 0°, the ratio of the two is practically constant, showing that, between 5° and 15°, *the osmotic pressure of cane-sugar solutions obeys the law of Gay-Lussac for gases.* A more recent series of measurements, not quite completed, shows that the same relation holds up to 25°. The ratio of osmotic to gas pressure at 0° is somewhat higher than at 5°, 10°, and 15°, namely, 1.074 as against 1.065, 1.061, and 1.064 (line *d*); but the series of determinations at 0° was made before the method of measuring osmotic pressure had

been developed to its present state, and a repetition of that work under the improved conditions may alter somewhat the ratio in question. On the other hand, it may be found that osmotic pressure, like the volume of the solvent, diminishes through a certain temperature interval above 0°. The measurements at 0° and at 5° will be repeated, and other series of determinations at 20°, 25°, and 30° will be carried out. That at 25°, as stated above, is already nearly finished, and the results lead to the same conclusion as do those at 10° and 15°.

An account of the work upon cane-sugar solutions at 10° and 15° will be found in the numbers of the American Chemical Journal for June and August, 1908.

Drs. B. F. Lovelace and W. W. Holland have cooperated with the author of this report in the work of the past year. He has also had, throughout that time, the valuable assistance of Messrs. B. Mears and H. V. Morse.

Noyes, Arthur A., Massachusetts Institute of Technology, Boston, Massachusetts. Grant No. 501. *Researches upon* (1) *Electrical conductivity of aqueous solutions at high temperatures;* (2) *Electrical transference determinations in aqueous solutions.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $3,000.

These researches have been continued during the past year in the Research Laboratory of Physical Chemistry of the Massachusetts Institute of Technology. The first has been executed with the assistance of Mr. Arthur C. Melcher, Mr. Roy D. Mailey, and Dr. John Johnston, and the second with that of Dr. Edward W. Washburn.

During the past year the following lines of work have been pursued:

(1) The conductivity and ionization of salts of the higher valence types in aqueous solution at temperatures between 0° and 156° have been determined; six salts (calcium nitrate, potassium oxalate, calcium and barium ferrocyanides, and lanthanum nitrate and sulphate) have been investigated in this way at a number of different concentrations. The results show that the higher the product of the valences of the constituent ions the smaller the ionization at a given temperature and concentration; that for all types the change of ionization with the concentration follows the same empirical exponential law (contrary to the requirements of the mass-action principle); and that in all cases the ionization decreases steadily with the temperature. This line of work is to be continued during the coming year.

(2) The solubilities in water of a few important difficultly soluble salts (calcium sulphate, barium sulphate, and silver chloride) have been determined up to 100° or 156° by measuring the electrical conductivity of their saturated solutions.

(3) A new form of platinum-lined steel bomb has been constructed, by which the specific volume, compressibility, and vapor-pressure of water can be determined between 310° and its critical temperature. Preliminary measurements of these quantities have already been successfully made; and the apparatus and measuring instruments have been accurately calibrated. The new form of bomb is also adapted to the measurement of the conductivity of solutions at these high temperatures.

(4) The research having for its object a study of the hydration of the ions of salts in aqueous solution by means of electrical transference measurements in the presence of a non-migrating solute, which has been in progress for over three years, has been brought to a conclusion, and a paper prepared describing the results. This investigation has conclusively demonstrated that the ions of the alkali elements are hydrated; and that the hydration increases in the order, potassium, sodium, lithium, while the equivalent conductance of these ions increases in the inverse order; thus affording an explanation of the long-known fact that the larger the atomic weight of the ion, the more rapid its rate of migration.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. Grant No. 414. *Investigation of the values of atomic weights and other fundamental physico-chemical constants.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $2,500.

Eight researches were conducted under the direction of Professor Richards with the support of grants from the Institution, as follows:

(1) An investigation of the atomic weights of lithium, chlorine, and silver, carried on with the assistance of Mr. H. H. Willard. Of this investigation the first part (concerning the atomic weight of lithium as obtained from the analysis of its chloride) is almost finished, and shows without doubt that the atomic weight of lithium is 6.94 (Ag = 107.88), or quite a per cent lower than the value found by Stas. The reason for the error of Stas has been discovered. The second part of the investigation, involving the analysis of lithium perchlorate, is well advanced; and many precautions which are necessary for exact results have been discovered and tested. It has been found that with proper treatment lithium perchlorate is exceedingly well fitted for the purpose of deciding the existing controversy as to the true atomic weight of silver with reference to oxygen. Mr. Willard, having obtained further leave of absence (through the courtesy of the authorities of the University of Michigan, where he holds an instructorship), will continue the work during the coming winter.

(2) An investigation concerning the atomic weights of nitrogen and silver, carried on with the assistance of Mr. F. B. Coffin. This work involves the analysis of ammonium bromide and supplements the work on ammonium

chloride carried on by the author and Drs. Köthner and Tiede in the University of Berlin. Many preparations of ammonium bromide have been prepared and analyzed with the greatest care, and conclusive evidence has been gained that the atomic weights of both nitrogen and silver are lower than Stas supposed them to be. The exact figures are not yet ready for publication. This work will be continued during the coming winter.

(3) An investigation concerning the compressibilities of the chlorides, bromides, and iodides of sodium, potassium, thallium, and silver, carried on with the assistance of Dr. Grinnell Jones. By means of the method of Richards and Stull, described in Publication No. 7 of the Carnegie Institution of Washington, the compressibilities of these substances were studied with great care. Regularities of a striking and interesting nature were found upon comparison of results, and the investigation led to the first rational explanation of the negative coefficient of expansion of silver iodide. The results of this research may be said to furnish the best support as yet offered for the theory of atomic compressibility, because they explain certain facts which might otherwise appear to be exceptions. Moreover, even supposing the theories should be disproved, the facts discovered in this investigation are certain to be of value. The paper has been prepared for publication and is now in press.

(4) An investigation of the relations exhibited by many physico-chemical properties of simple organic substances, carried on with the assistance of Dr. J. H. Mathews. For this purpose it was necessary in the first place to prepare large quantities of the substances in a state of great purity. When this had been accomplished, the substances (about 40 in number) were studied with regard to their surface tensions, compressibilities, heats of vaporization, boiling-points, vapor-pressures at 20°, and specific gravities. Relations between these properties of great interest and important significance were found, especially between surface-tension and compressibility. The relationship in this case was that predicted by the theory of compressible atoms; and the other relationships also, in so far as they are traceable, appear to be in accord with this theory. This investigation is finished, and is being prepared for publication.

(5) An investigation of the heats of reaction of metals upon acids, carried on with the assistance of L. L. Burgess. These data form the basis of computing the heats of formation of the salts of all metals. The determinations made previously by others made no pretense to be anything more than approximate, and advantage was taken of the exactness of the recently devised Harvard method of adiabatic calorimetry to redetermine these fundamental constants. Thus far the metals of magnesium, zinc, cadmium, aluminium, and iron have been studied, and in the following winter the work will be extended to other metals.

(6) The heats of neutralization of acids and alkalies, carried on with the assistance of Dr. A. W. Rowe. In this investigation also the adiabatic calorimeter was used, and modified for use with the rapid reactions involved. An important basis of this work is the specific heat of the reacting solutions; and it was quickly found that sufficiently accurate data for the purpose in hand have not been published. Therefore a new method of determining the specific heats of liquids—a method depending likewise upon adiabatic calorimetry—was devised, and with it the necessary specific heats were determined. A preliminary paper concerning this method has already been published (see Bibliography, pp. 45–52). A further statement of the results may well be reserved for the final publication. The research will be continued during the coming winter.

(7) A research concerning the specific heats of the elements at low temperatures. This work, begun in 1905 with the assistance of Messrs. G. E. Behr and R. F. Jackson, was continued during last winter with the assistance of Mr. F. G. Jackson. The specific heats of a large number of elements, especially metals, and of some other substances, between —190° and +20°, as well as between —78° and +20°, were determined with care, the methods of previous investigators being tested and compared. The results, taken in connection with the results of others, furnish a clear idea of the widely differing changes of specific heat suffered by different elements over wide ranges of temperature. The different curves show a distinct relationship to the periodic system of the elements and add another link to the chain of argument proving the intimate relation of each form of material to all others. This research has reached a stage where publication seems to be advisable, and the results will be published as soon as possible.

(8) An investigation concerning the energy changes involved in the dilution of the ammonium, zinc, cadmium, lead, tin, copper, thallium, and indium amalgams, carried on with the assistance of Mr. R. N. Garrod-Thomas (of Balliol College) and Dr. J. H. Wilson. This investigation is essentially a continuation of the previous investigation by Dr. G. S. Forbes, described in the reports given in Year Book No. 4. The objects of the research were to test the deviations of the electromotive forces from those required by the gas law, to test the equations of Helmholtz and Cady, and from the results to obtain further evidence concerning the nature of fluid amalgams in particular and liquid solutions in general. The results are interesting, amplifying as they do the results of Richards and Forbes while confirming them, and at the same time pointing out more than one inconsistency and inaccuracy in the work of previous investigators. This investigation (which was divided into two parts, each carried on by a separate assistant, using the same apparatus in a manner economizing both time and experimental energy) is finished and will be prepared for publication as soon as possible.

ENGINEERING.

Goss, W. F. M., University of Illinois, Urbana, Illinois. Grant No. 488. *Investigations to determine* (1) *the value of superheated steam when employed in single-expansion locomotives;* (2) *The performance of compound locomotives when served with saturated steam and when served with superheated steam.* (For previous report see Year Book No. 6, p. 194.) $3,000.

This grant provided for work to be done in cooperation with the locomotive laboratory of Purdue University and the outline approved was designed to cover four years' work. At the conclusion of the first year, September 1, 1907, a change in the location of the grantee made it impracticable to proceed according to the plan originally laid down, and it was agreed by all parties concerned that, for the present at least, the investigation should be concluded on the basis of work already accomplished. Fortunately, sufficient progress had been made to justify this action without loss. Prof. Goss had planned and completed a personal investigation of German practice in the use of superheated steam in locomotive service. The experimental locomotive of Purdue University, which had. by the courtesy of the American Locomotive Company, been especially prepared for the work by being equipped with a Cole superheater, had already been run 1,418,000 revolutions, equivalent to 4,851 miles. Thirty-eight tests had resulted from this process, a number sufficient to define clearly the performance of the existing superheating locomotive *Schenectady No. 3.* A formal report presenting the work accomplished will soon be ready for the printer.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. Grant No. 415. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $6,000.

The work under this grant has followed the lines set forth in previous reports. The following papers have been submitted for publication.

(1) A group of six correlated papers bearing on the tidal problem, in its relations to the earth's rotation and hence to its deformation. The specific titles of these papers and the authors are:

The former rates of the earth's rotation and their bearings on deformation, by T. C. Chamberlin.
The rotation period of heterogeneous spheroids, by C. S. Slichter.
On the loss of energy by friction of the tides, by W. D. MacMillan.
On certain relations among the possible changes in the motions of mutually attracting spheres when disturbed by tidal interactions, by F. R. Moulton.
On the possibility of fission of a contracting rotating fluid mass, by F. R. Moulton.
The bearing of molecular activity on spontaneous fission in gaseous spheroids, by T. C. Chamberlin.

(2) A paper on the results of an analytical study of the gases in rocks, by R. T. Chamberlin, with a discussion of the states in which the gases are held and their competency to serve as sources of atmospheric supply.

(3) A paper in three parts on geophysical theories under the planetesimal hypothesis, by Arthur C. Lunn, in which the evolution and distribution of terrestrial heat chiefly is considered.

(4) A paper on the relations of equilibrium between the carbon dioxide of the atmosphere and calcium sulphate, calcium carbonate, and calcium bicarbonate of water solutions in contact with the atmosphere, by Julius Stieglitz.

Seven additional papers are in advanced stages of preparation.

GEOPHYSICAL RESEARCH.

Adams, Frank D., McGill University, Montreal, Canada. Grant No. 503. *Continuation of investigation into the flow of rocks.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $1,500.

The investigations on the flow of rocks carried on during the past year follow two main lines of experimentation. The first of these consists of a series of experiments to complete the study of the relative strength of certain rocks before and after deformation. For this purpose Carrara marble was first employed, but the investigation was subsequently extended to Black Belgian marble, Solenhofen lithographic limestone, Trenton limestone, and to a series of typical dolomites—those from Cockeysville, Maryland; Lee, Massachusetts; and Portage du Fort, Canada, being chiefly employed. In the case of each rock columns of standard size were prepared, and after having been deformed their strength was tested in compression. This was compared with the strength of a column of the same shape as that assumed by the deformed column but cut from the original rock. The conditions of deformation were then varied, the rock being deformed at progressively higher temperatures and at progressively greater differential pressures, and the influence of these changing factors on the strength of the deformed rock was determined. In the case of Carrara marble the experimentation was carried further and the influence of the rapidity of deformation upon the strength of the resulting rock was ascertained, as well as the influence of time and temperature on the recovery of strength.

The experiments showed that certain calcareous rocks, of which Solenhofen limestone may be taken as an example, if deformed even with moderate rapidity under differential pressure at ordinary temperatures, will change their shape without loss of strength. In the case of Carrara marble the rock, if deformed quickly and at the ordinary temperature, is considerably weaker. If, however, the differential pressure under which the deformation is carried out is increased, the strength of the deformed rock also increases, as is also

the case if the deformation is carried on more slowly or at an increased temperature. It has been found, furthermore, that if a column of Carrara marble is deformed and is then allowed to remain undisturbed for several months, its strength will increase with rest, but that a column deformed at ordinary temperatures will not be increased in strength by a subsequent process of annealing.

In the case of dolomite it was found that while the strength of the rock when deformed under differential pressure was increased if the temperature during deformation was raised, and that while the rock after deformation remained firm and coherent, the loss of strength upon deformation was in all cases great.

This experimental work is now practically completed and a full report, describing the methods employed and embodying the results obtained by the study of a whole series of calcareous rocks, will be ready for publication before the close of the present year.

The second line of investigation to which reference has been made consists of an experimental study of rocks under conditions found in the "zone of flow." In these investigations Solenhofen limestone and Westerly granite have been employed. The columns of these rocks, penetrated by fine holes drilled through them in different directions, have been inclosed in tightly fitting tubes of nickel steel and submitted to compressive stresses of values calculated to exist at different depths within the earth's crust, the conditions of pressure in some experiments being those which according to hypothesis obtain in the "zone of fracture" and others those in the "zone of flow." This experimental work is not as yet in a sufficiently advanced state to enable general conclusions to be reached, more especially as the effect of the factor of temperature still remains to be studied.

Becker, George F., U. S. Geological Survey, District of Columbia. Grant No. 226. *Experiments on elasticity and plasticity of solids.* (For previous reports see Year Books Nos. 3, 4, 5, and 6.) $7,500.

Systematic observations on the elastic after-effect of steel tapes, to which reference was made in the last report, were resumed during the latter part of December, and are being continued with satisfactory results. As was mentioned last year, the temperature is controlled by means of an electric furnace operated in connection with an electric thermostat, and the measurements are made with a specially constructed interferometer. The design and construction of this interferometer has been a most difficult problem. The apparatus in its present form is quite satisfactory, but it is expected that improvements will be made as the work proceeds. The time interval during which the material is strained, or is allowed to recover from strain, ranges from 4 to 10 weeks, depending upon the magnitude of the strain. A second line of inves-

tigation with a similar piece of apparatus has consisted in studying the elastic after-effect of steel tapes at temperatures ranging from 30° to 150° C., for time intervals of 2 hours. This apparatus is to be used during the coming year in an investigation of the elastic properties of various metals at very high temperatures.

Some time has been given to a theoretical discussion of the data already obtained. It is expected that a portion of the work will be ready for publication in a few months. Incidental to a discussion of this data and certain problems in connection with the work of the Physical Laboratory of the Geological Survey, a 5-place table of the hyperbolic functions and some of the related functions has been prepared by Becker and Van Orstrand. The volume is being published by the Smithsonian Institution.

HISTORY.

Ferguson, W. S., University of California, Berkeley, California. Grant No. 338. *A history of Athens from Demosthenes to Plutarch.* (For previous reports see Year Books Nos. 5 and 6.) $1,200.

The volume on Hellenistic Athens, for which this grant was given, has not yet been printed. During the past twelve months the original materials for the work have been augmented considerably, the chief addition being made by the publication of the inscriptions found by the French excavators on Delos between 1904 and 1907. Moreover, through the kindness of friends in Europe Dr. Ferguson learned of the prospective publication of still further documents which would be valuable to him. Hence, apart from completing his "Researches in Athenian and Delian documents," and defending the chronological basis of his history by an article on the Athenian calendar, his time, since the last report, has been spent on a revision of the text of the book, which it is hoped will be finished for publication early in 1909.

Haskins, Charles H., Harvard University, Cambridge, Massachusetts. Grant No. 416. *Study of the documentary materials for Anglo-Norman History.* (For previous reports see Year Books Nos. 4, 5, and 6.) $1,000.

The work of the past year has centered mainly about the reign of William the Conqueror. A careful examination has been made of all available materials, both printed and unprinted, relating to the Norman side of this reign, with special reference to those institutions which are significant with respect to English constitutional development. The results of the investigation have been summarized in a paper on "Normandy under William the Conqueror," which was presented at the International Historical Congress in Berlin in August and will appear in the American Historical Review early

in 1909. A critical edition of the principal source for the study of early Norman law, the "Consuetudines et Justicie" of 1091, was published in the English Historical Review for July, 1908. A study of the administration of Normandy under Henry I is also ready for publication, and progress has been made with the calendar of ducal charters from 1035 to 1154.

LITERATURE.

Sommer, H. Oskar, "Astolat," Camberley, Surrey, England. Grant No. 489. *Preparation of results of researches on Arthurian romances.* (For previous reports see Year Books Nos. 5 and 6.) $2,000.

Dr. Sommer reports that the last year has been one of the most laborious and the most successful periods in his study of the Arthurian romances. He has been able to settle many disputed questions and his results have been embodied in two publications, which are listed in the bibliography in this volume (pp. 45–52).

About two months of Dr. Sommer's time during the past year were devoted to the study of manuscripts in the Bibliothèque Nationale, Paris, in the Biblioteca Estense, Modena, and in the Biblioteca San Marco, Venice. He has continued and completed the copy of ff. 129*a*–251*c* of the manuscript Add. 10293, forming the contents of the fourth volume of the Vulgate Version, or "Le Liure de Lancelot," Part II. This fourth volume has been collated with the corresponding portions of five other manuscripts at the British Museum, and Dr. Sommer has been able, by the help of the Paris manuscripts, to recognize four distinct successive stages in the development of the Lancelot. He will not be able to demonstrate fully what light this result will throw on the cycles which preceded the Vulgate until the Lancelot is printed, but proposes to outline briefly the results of all his studies so far in the preface to the Vulgate Version of the Arthurian Romances.

METEOROLOGY.

Bjerknes, V., and **Sandström, J. W.,** Christiania, Norway. Grant No. 490. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5 and 6.) $1,200.

Investigations of atmospheric motions from a purely kinematical point of view have been continued, attention being directed mainly towards the vertical movements. These can not generally be made the subject of direct observation, but by making proper use of the equation of continuity, they can be deduced from the observed horizontal components of the motion. Two different methods have been worked out for constructing the vertical

air-motions when the horizontal motions are given. These methods have been tried practically in a number of cases by constructing maps of the vertical air-motions derived from observations of the wind given on the common weather maps, and in this way the vertical motions sufficiently near the earth's surface are obtained with great ease. To obtain the vertical motions in the higher strata, observations obtained by kites and balloons, in connection with the observation of the motion of the clouds, will have to be used, but as yet it can not be stated whether sufficient observations for deriving vertical motion can be obtained by this method. This will be made the subject of further investigation.

The method stated can also be used for the investigation of the vertical motions on the sea, if observations of the horizontal motions are at hand; but lack of such observations renders the use of the method for oceanographic purposes very limited at present.

Some work complementary to the investigation of the statics of the sea has been performed, especially a recalculation of the hydrographic tables, using Dr. Ekman's new determination of the compressibility of sea-water. The work of drawing a topographical map of the world, for use in investigations relating to the dynamics of the atmosphere and the sea, has also been continued.

NUTRITION.

Mendel, Lafayette B., Yale University, New Haven, Connecticut. Grant No. 265. *Study of the physiology of growth, especially in its chemical processes.* (For previous reports see Year Books Nos. 4, 5, and 6.) $2,000.

The investigations on the physiology of growth which have been facilitated by this grant have been published in a series of papers reported in the bibliography on pp. 45–52. They indicate that the equipment of the growing or developing animal organism for its physiological work is in various respects different from that of the adult. This applies especially to the distribution and richness in enzymes and is well illustrated in the case of purine-converting enzymes (see Chemical Studies on Growth, II). The synthetic capacity of the embryonic tissues has also been emphasized (*e. g.*, in Chemical Studies on Growth, VI).

The study of the influence of diet on the chemical composition of the body clearly emphasizes the attempt of the animal organism to maintain a fixity in its fundamental tissues. The fat and water content of the body tend to vary in inverse relation. High fat-content is accompanied by low water-content. But aside from the deposition of fat it is practically impossible, by alimentary methods, to alter the fundamental composition of the active

parts or to deprive the body of any constituent which is fundamentally important for its functions. A lack of certain customary constituents in the diet does not lead to the formation of a new type of tissue and altered chemical phenomena of growth. Normal growth can proceed only when all the essential constituents are available for assimilation; and the withdrawal of these is accompanied by a general and uniform disintegration, so that the relative composition of the remaining tissues continues unaltered. The bearing of these facts upon nutrition and dietetics is obvious.

Osborne, Thomas B., Connecticut Agricultural Experiment Station, New Haven, Connecticut. Grants Nos. 439 and 497. *For work on vegetable proteins.* (For previous reports see Year Books Nos. 3, 4, 5, and 6.) $9,000.

Grant No. 439 ($5,000).—During the past year satisfactory progress has been made with work done under this grant, for experience with the methods employed has made it possible to obtain results more rapidly than formerly.

The only serious obstacle to the progress of the work was presented by an unfortunate accident to the liquid-air apparatus belonging to the Sheffield Scientific School of Yale University, which institution has generously furnished Dr. Osborne with a liberal supply of liquid air which is necessary for his work. As about three months were required to repair the apparatus, the number of hydrolyses of the proteins which it was possible to complete was correspondingly reduced, for during this interval liquid air could be obtained from no other source.

Nearly all the more important proteins of seeds used for nutrition of men and domestic animals have now been hydrolyzed, and definite knowledge obtained as to the relative proportions of their decomposition products. It is intended to prepare a detailed summary of the work done along these lines under this and previous grants, in which the more important questions relating to these hydrolyses will be fully discussed.

During the year the following work, described in the last Year Book as in press, has been published, as shown in the bibliography, page 50: Hydrolyses of the proteins of maize, of amandin from the almond, and of gliadin from rye.

Hydrolyses of vicilin and of coagulated legumelin from the pea (*Pisum sativum*) have been completed and the results published in the Journal of Biological Chemistry. The results of the hydrolyses of legumin from the vetch and of vignin from the cow-pea (*Vigna sinensis*) have appeared in the American Journal of Physiology.

In accord with the plan originally outlined for this work, hydrolyses of some of the more important animal proteins have been made in order to compare the proportion of their various products of hydrolysis with those of the

food proteins of vegetable origin. The information on record concerning the proportion of products of hydrolysis of the meat proteins is very meager, for it comprises but one incomplete hydrolysis of beef "syntonin."

As nothing definite is known in respect to chemical similarities and differences between the proteins of the different kinds of meats, hydrolyses have been made of the muscle substance of chicken and fish (halibut), the results of which have been published in the American Journal of Physiology. These results show that distinct differences exist in the proportion of several of the decomposition products of the muscle substance of these two species. Both yielded over 7 per cent of lysine, a quantity larger than has yet been obtained from any other true protein, and far in excess of that found in most of the seed-proteins. In respect to the proportion of their decomposition products, these muscle substances more nearly resemble the proteins of the leguminous seeds than those of any other group of plants, and differ most widely from those of the cereals.

Two hydrolyses of the albumin of the white and three hydrolyses of the vitellin of the yolk of hens' eggs have already been published by others, but their results were so divergent that it was thought advisable to repeat the hydrolyses of these important food-proteins in order to show which of the published figures were correct. It was also hoped to thus obtain data which would show how close an agreement could be expected between the results of experienced investigators working entirely independently of each other. Both these expectations have been attained and the results will soon be published.

Many data concerning the basic decomposition products of a considerable number of proteins have been gradually accumulated during the last four years, and especial attention has been directed to this subject during the past year. An attempt has been made to determine with a high degree of accuracy the proportion of the basic decomposition products, to test the capabilities of the available methods, and to record the best conditions for carrying them out. This work has led to some important results and has recently appeared in the Journal of Physiology.

An investigation was also made of the primary or secondary origin of pyrimidine derivatives of nucleic acids. Although this is not a question of protein chemistry, the close association of these substances in the tissues makes a knowledge of the chemistry of one important for a knowledge of the chemistry of the other. As the question investigated had become the subject of much controversy and was one of fundamental importance to the chemistry of the nucleic acids, it seemed worth while to devote a short time to experiments with a supply of nucleic acid from the embryo of wheat which remained over from previous investigations made in this laboratory. The results of these experiments furnished conclusive proof that the pyrimidine derivatives do not originate from the purines, and that they are primary

derivatives unless they result from the closing of a straight chain during the process of hydrolysis. These results were published in the American Journal of Physiology, as shown in the bibliography, pp. 45–52.

Grant No. 497 ($4,000).—Work under this grant is progressing satisfactorily, but, as it is only a short time since its commencement, the results are not yet ready to report. The work now under way includes hydrolyses of the more important food-proteins of animal origin, and it is expected that these will be completed within the year.

PALEONTOLOGY.

Wieland, G. R., Yale University, New Haven, Connecticut. Grant No. 491.
Taxonomic (and structural) study of American fossil cycads. (For previous reports see Year Books Nos. 2, 3, 4, and 6.) $2,000.

Following the preliminary studies of foreign collections mentioned in Year Book No. 6, the present year has been taken up quite entirely in as yet incompleted laboratory work on thin sections, and more lately in the preparation of manuscript for a volume on the taxonomy of the American fossil cycads, complementary to that already published on structure.

PHILOLOGY.

Flügel, Ewald, Stanford University, California. Grants Nos. 329 and 460.
The preparation of a lexicon to the works of Chaucer. (For previous reports see Year Books Nos. 3, 4, 5, and 6.) $11,000.

Dr. Flügel reports that the year's work has been devoted mainly to the alphabetizing and arranging of accumulated slips, which have reached in number about 1,120,000. This part of the work was done under Dr. Flügel's superintendence by Dr. H. Ram, Mr. Chester Rand, and Mr. Wood, of Stanford University. Mr. H. Geer, as a volunteer assistant, has assorted the slips of the "pronouns of address" (thou, thee, you, ye, etc.).

Besides his work as alphabetizer, Dr. H. Ram has copied quotations from Froissart and prepared word-indexes to several Middle English authors. Prof. E. Einenkel, of Halle, has finished his share of the prepositions, indefinites, etc., for the letter A, while Dr. Flügel's own share was the superintendence of the work along all these lines and the final editing of the letter A, which is now completed but for a last revision of the text. He hopes to have the letters B and C ready by the end of the winter.

PHYSICS.

Barnett, S. J., Tulane University of Louisiana, New Orleans, Louisiana. Grant No. 149. *Investigation of the electric displacement and electric intensities produced in insulators by their motion in a magnetic field.* (For previous reports see Year Books Nos. 3, 4, 5, and 6.) $250.

The work abstracted in the last report, together with that accomplished since, has been published.* The effect has now been studied with four different insulators, and in all cases Lorentz's theory has been confirmed. The effect in question could not be studied with some of the cylinders prepared, for reasons given in the complete paper. In two cases the motional e. m. f. under investigation was masked by a much larger e. m. f., radial in direction, independent of the magnetic field, and proportional to the square of the angular speed. While a true centrifugal differential displacement of the oppositely charged constituents of matter, which this result would suggest, doubtless exists, its theoretical magnitude, even on the most favorable hypothesis in the case of conductors, is far less than the effect obtained would indicate. And other important reasons exist for discarding such an interpretation of the observations, for which no satisfactory explanation has been found. Experiments on this effect and on the electromagnetic effect are to be continued. The complete paper contains corrections of two erroneous statements made in the abstract.

Barus, Carl, Brown University, Providence, Rhode Island. Grant No. 505. *Study of the character of properties of condensation nuclei.* (For previous reports see Year Books Nos. 4 and 5.) $500.

(1) During the earlier part of the year Dr. Barus continued his investigations on the nuclei of pure water with regard to their size and persistence. These nuclei are obtained by the precipitation of water on the nuclei of water-vapor, in a dust-free fog-chamber, by sudden cooling. The fog-particles so obtained evaporate to water nuclei on compression, the number of the latter as compared with the former being greater as the evaporation of fog-particles is more rapid and as their size is larger. In the extreme case nearly 50 per cent of the fog-particles were represented by these residual water-nuclei. It was a curious observation that whereas the relatively enormous fog-particles of pure water evaporate at once beyond the range of visibility, such evaporation stops in cases of certain of the invisible water particles (0.5 to 50 per cent of the total number of fog-particles), as the evaporation is more rapid in the manner specified. The remaining fog-particles evaporate completely. It was impossible to detect any electrical effect due to rapid evaporation. The cause of these phenomena is difficult to ascertain, but it may be suspected that it is associated with the composite nature of the molecule of liquid water.

* Physical Review, November, 1908.

(2) In a succeeding investigation Dr. Barus made further studies of the optics of coronas. It was shown that the interference phenomenon superimposed upon the diffraction phenomenon in the case of coronas may be treated in a way similar to the lamellar grating, consisting of a uniform succession of alternate strips of thin and thicker transparent glass. Given types of coronas are reproduced in successively increasing size, when the respective fog-particle diameters are in the ratio of . . . . 5, 4, 3, 2, 1, 0. The ratio of fog-particle diameter d and interference-plate thickness D for the same color minimum in the interferences and a film of water is $d / D = n\ (n - 1)$, where n is the index of refraction of water. The experimental values of d / D agree well with this. It must therefore be possible to compute the nucleation corresponding to a given corona, purely from optical considerations of diffraction and interference, as indicated. To further verify the theory suggested, special study was made of the axial or interference colors of coronas, by the aid of large drum-shaped chambers 2 meters long.

The coronas obtained with electric light are almost too complicated for practice, for which reason a part of the mantle of a Welsbach burner has usually been used as a source of light. Much better results are obtained, however, by the use of the virtually monochromatic mercury lamp as a source. This is sufficiently intense and admits a more definite optical interpretation. Experiments have therefore been in progress to standardize these simplified coronas by the method of successive exhaustions and phosphorus nuclei. The work is now practically finished and all anticipations have been realized.

(3) In an endeavor to standardize the coronas in terms of the nucleation involved, by the aid of separate small batches of sealed radium, used singly or in groups, very little progress was made, because the coronal diameter varies as the sixth root of the intensity of ionization. The experiments, however, lead to certain remarkable results on the distribution of ionization, with reference to the position within the fog-chamber of the sealed aluminum tube (beta and gamma rays being in question, largely the latter) containing radium. If the parts of the fog-chamber consist of different materials or not, the maximum ionization due to primary and secondary radiation rarely coincides with the position of the radium. In a horizontal cylindrical fog-chamber, closed at one end and open for exhaustion at the other, the maximum ionization is found to move from the closed end to the exhaustion end, as the radium moves from the closed end to the middle of the chamber. As the radium moves further the maximum remains near the exhaustion end, but the ionization diminishes in marked degree throughout the whole chamber. The ratios of ionization are frequently greater than 2 to 1. To obtain maxima of ionization near the middle of the chamber the sealed radium tube must be near the closed end. In other adjustments even minimum ionization was producible in the middle, as compared with the ends. It appears from the

results that it is possible to appreciably displace the ions during the period of exhaustion, the reproduction being insufficiently rapid.

(4) In a final investigation the endeavor was made to standardize the coronas in relation to the number of fog-particles represented under given circumstances of exhaustion, by aid of Thomson's electron. After a number of trials, the first successful method consisted in making a closed aluminum tube containing an even distribution of radium the core of a cylindrical condenser, leaded to an inch or more in thickness without. This core was suspended axially from fine wire, leading to Dolezalek's electrometer for the measurement of the small voltages and currents involved. The core in question was then removed from the electrical condenser and put into the axis of a dust-free fog-chamber, where the nucleation (ionization) was found from the constants of the coronas obtained upon exhaustion, or *vice versa.*

Using the method which depends essentially on the velocity of the ions in the unit electric field and his earlier values of the constants of coronas, Dr. Barus made a few rough tests of the charge of the electron, which gave very reasonable values. Experiments made under different conditions showed, for instance, $e \times 10^{10} = 3.7, 4.3, 3.8, 3.4$ electrostatic units of charge in the different cases, whence it follows that both positive and negative ions must have been captured.

There was, however, an inherent difficulty of great importance, the nature of which has already been referred to. The ionization differs in different parts of the fog-chamber and the extreme ratios may exceed 2 to 1. It does not follow, therefore, that the mean ionization observed in the fog-chamber is the same as that obtaining within the heavy leaded electrical condenser. To secure this identity the fog-chamber itself must be the condenser.

The method was, therefore, varied by using the cylindrical fog-chamber (glass wet within, put to earth), with its axial core of charged aluminum tube, both as an electrical condenser for the measurement of current and as a fog-chamber for the measurement of ionization. The end of the aluminum tube within the fog-chamber is hermetically sealed; the other is open without for the introduction of the sealed tubelets containing radium. By properly adjusting these along the axis, an approximately uniform ionization within the fog-chamber is obtainable. The trials made seemed promising enough to make it worth while to repeat the determination of e by Thomson's method, using, however, the mercury lamp as a source of light and a purely optical method for the measurement of the nucleation, as suggested above.

(5) The correlative method of determining e in terms of the decay constant $b = 1.1 \times 10^{-6}$ of the ionization has also been tried. If N be the number of ions in the fog-chamber due to the radium in the aluminum tube when the latter is not charged and n the number when it is charged, the constant e may be written $e = C\dot{V} / [b(N^2 - n^2)v]$, where C is the capacity and v the volume of the cylindrical condenser-fog-chamber and $\dot{V}$ the (constant) fall of

potential of the core per second, due to the current passing through the ionized air within the chamber. In this case, very large potentials (250 volts) may be used and a graduated Exner electroscope suffices for the measurement of $\dot{V}$.

The experiments made for the present merely to test the standardization of the fog-chamber, as detailed in the earlier publications of the Carnegie Institution of Washington, nevertheless lead to very acceptable values of e. For instance, if all data are expressed in electrostatic units, i being the current,

c	$\dot{V} \times 10^3$	$i \times 10^2$	$e \times 10^{10}$
103	7.5	77	3.3
47	17.2	81	3.5
37	19.6	72	3.1

From which it again follows that both positive and negative ions must have been captured even at the enormous ionizations, exceeding 500,000 nuclei per cubic centimeter, employed.

Burgess, Charles F., University of Wisconsin, Madison, Wisconsin. Grant No. 430. *Investigation of the properties of electrolytic iron and alloys made from it.* (For previous reports see Year Books Nos. 4, 5, and 6.) $2,500.

During the summer and fall of 1907 progress on the work was not as rapid as it had been, due to inability to secure the necessary amount of competent assistance. Since the first of this year the investigation has proceeded more satisfactorily with the services of Mr. James Aston, who has devoted his entire time to the work.

From July 1, 1907, until August 1, 1908, ten tanks have been running continuously in the production of electrolytic iron, the output being 450 pounds of single-refined and 570 pounds of double-refined iron.

Most of this iron has been used in the manufacture of iron alloys for test purposes, but, in addition to this, quantities of refined iron, varying in amounts from 1 ounce to 50 pounds, have been furnished to various parties wishing to investigate its properties. On account of the high purity of the double-refined iron it appears that it is a suitable material for standardizing purposes, and arrangements are being made to supply the material required for this purpose.

The production of iron alloys has been continued, and there are now on hand, and undergoing test for physical properties, 301 binary alloys and 218 alloys containing more than one alloying element. In the manufacture of these alloys the attempt has been made to keep down the carbon content to

the lowest possible point. Some interesting and apparently important results have been shown through the magnetic and other tests, and definite announcement of the results is awaiting the completion of the chemical analyses.

Incidental to this investigation the influence of strain and the crystalline structure upon the corrodibility of iron were studied, results of which are given in detail in "The corrosion of iron from the electrochemical standpoint" (Presidential address, C. F. Burgess, Transactions American Electrochemical Society, vol. 13, 1908).

Various attempts have been made in the past, both in connection with this investigation and in the investigation by others to alloy iron and calcium, and the opinion seemed to prevail that such an alloy could not be produced. During the past year, however, Alcan Hirsch and James Aston have succeeded in producing iron-calcium alloys, and have shown that the previous failures to alloy these two metals have been due to the volatility of calcium at such temperatures as are necessary to melt iron. They succeeded in producing the alloys by conducting the melting operation under pressure. Their results are given in "The alloying of calcium and iron" (Transactions American Electrochemical Society, vol. 13, 1908).

Howe, Henry M., Columbia University, New York, New York. Grant No. 504. *Completion of work of determination of the influence of ingot size on the degree of enrichment of the segregate in steel ingots, and the homogeneousness of the ingots outside the region of maximum enrichment.* (For previous report see Year Book No. 6, pp. 215, 216.) $300.

Professor Howe reports that in order to determine more exactly the position and richness of the most enriched point, many additional drillings have been taken from the ingots previously examined.

Two more large ingots have been examined with care. Six more ingots have been cast under special abnormal conditions in order to test the theory formed as to mechanism of segregation.

The inferences drawn in Professor Howe's last report are confirmed by the further data collected during the year, with the exception that in several ingots the most enriched point is not axial. The reason for this surprising phenomenon is not known, but on inquiry it was found that it has been observed by J. O. E. Trotz, of Worcester, Mass.

A large amount of work has been done in reducing the results now obtained.

Lewis, E. Percival, University of California, Berkeley, California. Grant No. 150. *Photographic investigations of vacuum-tube spectra of gases and vapors.* (For previous reports see Year Books Nos. 3, 4, 5, and 6.) $500.

With the permission of the President of the Institution, Professor Lewis accepted the invitation of Director Campbell to take the quartz lenses and

prisms purchased under the above grant on the Crocker eclipse expedition to Flint Island. After spending several months in mounting these in a temporary wooden spectrograph suitable for the purpose, Professor Lewis sailed with the expedition November 22, 1907. The expedition was entirely successful, as shown in the report published in Lick Observatory Bulletin No. 131. The results obtained with the quartz spectrograph are published in detail in that bulletin. An excellent spectrum of the corona was obtained, showing at least two new and intense lines, undoubtedly of coronal origin.

Professor Lewis is now engaged in taking up the regular work of studying the ultra-violet spectra of compounds. A number of films were made last year, but the results are not yet reduced.

Nichols, Edward L., Cornell University, Ithaca, New York. Grant No. 286. *Quantitative study of fluorescence and phosphorescence, especially at low temperatures.* (For previous reports see Year Books Nos. 4, 5, and 6.) $1,000.

The investigations carried on during the year 1907–08 may be summarized briefly as follows:

(*a*) *The Experimental Study of Cathodo-luminescence, by Professors Nichols and Merritt.*—This work consists of a preliminary exploration of an important field in which hitherto little or no quantitative investigation has been carried out. Definite results have been obtained and several general principles have been established which serve as a basis for further study. The results are in preparation for publication in the Physical Review.

(*b*) *The Quantitative Study of Thermo-luminescence, by Dr. C. A. Pierce.*—This work, which forms the subject of two papers* in the Physical Review, affords the first systematic quantitative investigation of the relations which govern thermo-luminescence, together with suggestive theoretical deductions. The research is being further pursued by Mr. Pierce, who is applying to the same a new and interesting photographic method of attack.

(*c*) *The Effect of Temperature upon the Absorption and Fluorescence of Solids, by Mr. R. C. Gibbs.*—This work, which will ultimately be extended to various substances and will cover a wide range of temperature, has been completed so far as the study of the effect of high temperatures upon the absorption and fluorescence of uranium glass is concerned. Mr. Gibbs's results, which will appear in the Physical Review, afford a complete and interesting graphical representation of the changes in the absorption bands of this substance as the result of heating and of the corresponding modifications in the character of the fluorescence spectrum. The spectrum is found to consist of several overlapping bands, some of which vanish gradually as the temperature rises, while others are comparatively unaffected. The result is a striking modification of the composition of the fluorescent light.

* C. A. Pierce: The Physical Review, vol. xxvi, No. 4, and vol. xxvi, No. 6.

The immediate extension of this investigation upon which Mr. Gibbs is already engaged consists in a similar spectrophotometric study of the absorption and fluorescence of this substance at very low temperatures.

(*d*) *The Study of Short Time Phosphorescence, by Mr. C. W. Waggoner.*—This research is being carried on with a new type of phosphoroscope devised by Professor Merritt, which makes it possible to measure and plot the curves of decay of intensity of the phosphorescent light from various substances, wave-length by wave-length, throughout the spectrum in cases in which the duration of phosphorescence is too brief to permit of observations by the methods hitherto employed. The results obtained are of great theoretical importance in their bearing upon the law of decadence of phosphorescence.

In the course of his investigation Mr. Waggoner has had occasion to prepare a large number of phosphorescent compounds of definite and known composition and treatment. The study of fluorescence and phosphorescence in the past has been largely confined to substances of unknown composition and the most promising field for future investigation undoubtedly lies in the systematic quantitative study of these definite compounds. To this branch of the subject Mr. Waggoner and other workers intend to turn their attention in the future. The results already obtained by Mr. Waggoner are described in a paper* recently published.

(*e*) *The Study of Selenium Films, by Miss L. S. McDowell.*—While selenium films do not show the phenomenon of phosphorescence, the changes in resistance which they undergo after exposure to light have been found to correspond in a remarkable manner with the law of decay of phosphorescence. The experiments of Miss McDowell have therefore an important bearing upon the theory of phosphorescence in that they indicate the close connection of this subject with numerous other phenomena and suggest hitherto unsuspected relationships.

(*f*) *The Effect of Light on the Electrical Conductivity of Fluorescent Solutions, by Dr. Percy Hodge.*—This important work which has been in progress for nearly two years has recently begun to yield definite results of great interest. In a paper already submitted to the Physical Review, Dr. Hodge deals with the phenomena in so far as electrolytic cells with fluorescent solutions are concerned. The change in electrical conductivity of such cells is found to be a phenomenon residing in the layers of liquid in the immediate neighborhood of the cathode of the cell. The changes, which are of a complicated nature and appear to depend upon many factors, are studied *in extenso* in Dr. Hodge's paper. It has been found that cells with platinum electrodes and a fluorescent solution, when illuminated, develop independent

* C. W. Waggoner: The Physical Review, vol. xxvii, No. 3.

electromotive forces without the passage of an electric current from the outside. These photo-electric effects constitute the subject of a further investigation which is now in progress at his hand.

(*g*) *The Mathematical Theory of Luminescence, by Professor Merritt.*— This theoretical work which is based upon the experimental results obtained in the course of our experiments, together with such other fragmentary data as were available, have appeared in the form of a paper in the Physical Review.* It is intended to make this, in a more elaborated form, the closing chapter of the series of investigations completed under the grant from the Institution. The equations formulated by Professor Merritt express and connect in a systematic way the complex and varied phenomena hitherto obtained. They enable one, for the first time, to predict results and prescribe the conditions under which further experiments are to be performed.

A final report, in the form of an extended memoir covering the ground of these investigations and of those which have been mentioned in earlier reports of progress, will be submitted as soon as the voluminous material in hand can be prepared for publication. The work thus far accomplished, although it has taken the time of several observers for a number of years, is to be regarded only as a preliminary survey. In this important field of optics very few quantitative measurements had been made up to the time when these investigations began, and it is believed that the detailed study of definite compounds which is now in contemplation will yield important results.

PHYSIOLOGY.

Loeb, Leo, University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 528. *The toxic action of the poison of Heloderma suspectum.* (For previous report see Year Book No. 6, p. 218.) $500.

Professor Loeb reports that during the past year the following work has been carried out in the Laboratory of Experimental Pathology of the University of Pennsylvania:

In collaboration with Miss Elizabeth Cooke, he has investigated—

(1) The general physiological effects of the venom when it is administered to different species of vertebrates and the macroscopic changes to which it gives rise.

(2) Some of its physiological properties, viz, its behavior towards heat, filtration, and dialysis.

(3) Its hæmolytic action upon the erythrocytes of animals of different species.

(4) Place of origin of venom.

Dr. D. Rivas has investigated the pathological action of certain bacteria obtained from the mouth secretion of *Heloderma.*

* E. Merritt: The Physical Review, vol. XXVIII, p. 367.

Dr. Henry Fox has studied the anatomical and histological structure and genetic relationships of the poison gland.

Dr. Lucius Tuttle and Dr. Milton K. Myers have studied the changes produced in the blood-cells of various animals after inoculating them with venom.

In collaboration with Dr. Lucius Tuttle, Dr. Loeb has investigated the effect of certain fluorescent substances upon the venom.

At Woods Hole, in collaboration with Miss Cooke, the following studies were made:

(1) The physiological action of the venom upon various species of invertebrates.

(2) Its influence upon the development of the eggs of the starfish and sea urchin.

(3) Its effect upon the heart action of *Limulus*.

Besides the foregoing completed studies, the following unfinished ones are in progress:

(1) Studies in immunity.

(2) Microscopic changes produced by injecting the venom into other animals.

The following studies are planned:

(1) A chemical investigation of the venom.

(2) A more detailed study of some of the physiological effects of the venom.

Reichert, Edward T., and **Brown, Amos P.**, University of Pennsylvania, Philadelphia, Pennsylvania. Grant No. 517. *Completion of research on the crystallography of hæmoglobins.* (For previous reports see Year Books Nos. 3, 4, and 6.) $1,000.

The work under this grant has now been completed, and it is expected that the results of the research will shortly be presented to the Institution for publication.

POLITICAL SCIENCE.

Rowe, Leo S., University of Pennsylvania, Philadelphia, Pennsylvania. Grants Nos. 144 and 496. *Study of the federal system of the Argentine Republic.* $1,500 each. $3,000.

Professor Rowe reports that his investigations have led to the completion of reports upon the following subjects:

The social basis of Argentine democracy.
The foundation of the Argentine federal system.
The antecedents of the Argentine Constitution.
The Constitution of 1853 and the amendments of 1860, 1866, and 1898.
The division of functions between the federal government and the provinces.
The constitutional position of the provinces.

Reports upon the principles and practice of federal intervention and upon the political influence of the federal government on the provinces are in course of preparation.

Throughout the work essential points of contrast between the constitutional practices in Argentina and in the United States are considered.

PSYCHOLOGY.

Franz, Shepherd Ivory, Government Hospital for the Insane, Washington, District of Columbia. Grant No. 80. *For investigation of the functions of the cerebrum, with special reference to the functions of the association areas.* (For previous reports see Year Books Nos. 4, 5, and 6.) $1,000.

Dr. Franz reports general progress on his work under the above grant. The work on the parieto-occipito-temporal association area has been continued, and he has had the opportunity of examining Dr. C. B. Farrar's specimens of monkey brains used in a previous research on frontal lobes, but no new results have appeared in this examination.

During the year Dr. Franz has published three articles in which results on the frontal lobes are further discussed. (See bibliography, pp. 45–52.)

ZOOLOGY.

Castle, W. E., and **Mark, E. L.,** Harvard University, Cambridge, Massachusetts. Grant No. 492. *Continuation of experimental studies in heredity.* (For previous reports see Year Books Nos. 3, 4, 5, and 6.) $500.

Dr. Castle states that the study of color inheritance during the past year has shown the existence of several new color factors, and has led to simplified methods of expressing gametic and zygotic formulæ and to a simpler conception of the material basis of heredity factors. Hybrids between *Cavia aperea* and the guinea-pig, though regularly sterile in the male sex, have been found to be commonly fertile in the female sex, with the guinea-pig male, and to some extent at least with the *aperea* male. Cuénot's theoretically important discovery that dark-eyed yellow mice are regularly heterozygous has been confirmed. Other investigations are in progress, two papers are in manuscript, ready for publication, and two brief papers have been published during the year. Five students have assisted in the investigations.

Dr. Mark reports that, as contemplated, his work has been extended to the study of insects.

(1) Investigations on the spermatogenesis of certain Hymenoptera (honey-bee and mud-wasp) carried on in conjunction with Dr. Manton Cope-

land, have been completed and an adequately illustrated manuscript will shortly be ready for publication.

(2) Considerable time has already been given to the investigation of certain parasitic Hymenoptera, with a view to determining the precise conditions of parthenogenetic reproduction in them, to producing hybrids, and to ascertaining the conditions of the chromatin during reproduction. This material is found to be more available and more easily controlled than that of vertebrates, so that for the present more attention will be given to the invertebrates. In this work Dr. Mark expects to have the assistance of one or more students during the coming year. While the first cost of this material is slight, the need of large numbers of preparations necessitates the employment of expert technicians to prepare microscopic slides.

Dr. Mark believes that this work will be of much theoretical value, and may possibly lead to the solution of practical questions in the propagation of parasitic Hymenoptera to control noxious insects.

Crampton, Henry E., Columbia University, New York, New York. Grant No. 431. *The study and collection of gasteropod mollusca of the genus Partula.* (For previous report see Year Book No. 6.) $3,000.

Dr. Crampton reports that in May, 1908, a second journey was undertaken to the Society Islands, to extend the field of investigation so as to include the leeward islands of the group. Eleven weeks and more were spent in actual field work.

In all about 40,000 specimens were taken from 95 valleys and stations in the islands of Raiatea, Tahaa, Huaheine, and Borabora. More than 1,000 specimens were also procured from certain important valleys of Tahiti, previously explored. Therefore there is now in hand abundant material for a thorough statistical examination of the variation of species of the genus *Partula* inhabiting the Society Islands, where the greater number of known species of the genus may be found. Each island that possesses Partulæ has been explored, and a special study has been made in each case of variation and its possible relation to environment, in respect to climatic, geological, physiographic, and heterogeneric biological conditions. Of special importance is the availability of the material for the comparison of the snail faunas of neighboring islands, separated by different degrees of distance. Tahiti and Moorea are 10 miles apart and Raiatea and Tahaa are four miles apart, but they are encircled by a common coral-reef, while Huaheine is a double island whose two halves nearly touch. Moorea and Tahiti are 70 miles from Huaheine, the nearest member of the leeward group, while Borabora is 20 miles beyond Raiatea. Therefore the snails of the various valley systems of these couples or groups may be compared in the study of a larger distributional problem as well as with respect to their variation within the island limits.

Although the quantitative results must await announcement until a thorough study has been made of all the individuals collected, certain qualitative results of importance may be stated at the present juncture. The occurrence of mutation in several species from the leeward islands has been demonstrated, thus confirming in principle the conclusion offered last year, based upon the study of the snails of Tahiti and Moorea. The mutants may arise in the older portions of the habitat of a species as well as in newly-acquired territory. Finally, environmental factors do not seem to be the active or direct causes of mutation or of variation as distinguished from mutation.

Gudger, E. W., North Carolina State Normal and Industrial College, Greensboro, North Carolina. Grant No. 529. *Investigation of the breeding habits and the life-history of the gaff topsail catfish.* $300.

Thus far Dr. Gudger's work has consisted in collecting material, making notes, and supervising the work of the artist making the drawings. The investigation is as yet in an early stage, and the results will not be ready for publication for a year or two.

Howard, L. O., United States Department of Agriculture, Washington, District of Columbia. Grant No. 250. *Preparation of a monograph on American mosquitoes.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $3,000.

The report for the past year is simply one of general progress. Messrs. H. G. Dyar and Frederick Knab, both employees of the Bureau of Entomology of the U. S. Department of Agriculture, have beeen working steadily on the manuscript of the classificatory portion of the volume. Dr. Howard has been working upon the features which deal with remedial work, and with disease. He has taken several trips to investigate large-scale remedial work being carried on. Mr. Knab has also been engaged in completing a series of drawings of the early stages. The monograph is fast approaching completion, and will soon be submitted for publication. In the course of the work two short papers by Mr. Knab have been published. (See bibliography, pp. 45–52.)

Mark, E. L., Harvard University, Cambridge, Massachusetts. Grant No. 506. *Study of maturation and early stages in the development of the ova of mice.* (For previous reports see Year Books Nos. 5 and 6.) $300.

The work under this grant has been carried forward successfully by Dr. Mark, in collaboration with Dr. J. A. Long, and the results are embodied in a paper about ready for publication. A preliminary account of some of the results reached in the study of the chromosome-number were presented at the New Haven meeting of the American Society of Zoölogists in December, 1907, and subsequently published in Science, as shown in the bibliography on pp. 45–52 of this volume.

Time did not permit Dr. Long to carry very far that branch of the work which had to do with the production of hybrids by means of artificial in-

semination; but Dr. Mark has made arrangements for the continuation of that part of the work during the coming year.

Naples Zoological Station, Naples, Italy. Grant No. 493. *For maintenance of two tables.* (For previous reports see Year Books Nos. 2, 3, 4, 5, and 6.) $1,000.

During the year the following American naturalists have been assigned to tables in the Zoological Station: Prof. Alfred G. Mayer, from November 25, 1907, to February 27, 1908; Dr. Elliot R. Downing, from February 1 to May 25, 1908; Mr. Charles S. Mead, from April 28 to May 22, 1908; Dr. Stewart Paton, from October 17, 1907, to June 27, 1908.

Wilson, Edmund B., Columbia University, New York, New York. Grant No. 370. *Researches on the chromosomes of insects and other animals with reference to the cytological basis of sex-production and Mendelian inheritance.* (For previous reports see Year Books Nos. 5 and 6.) $500.

This grant was made only for the collection of material in 1906, but a part of the work carried on since then has been based upon the material thus collected. During the past year the work has been carried on by Professor Wilson, Mr. F. Payne, and Mr. C. V. Morrill.

Professor Wilson has completed and sent to press a study of the genus *Metapodius*, which forms the fifth of his series of "Studies on Chromosomes." This paper deals especially with forms that contradict the usual rule of specific constancy in the number of chromosomes. The study of an extended series of material proves that the variation affects only a particular class of chromosomes, the "supernumeraries," that undergo a variable distribution to the gamete-nuclei, and hence produce corresponding variations in the zygotes. Detailed analysis of the facts lends strong support to the hypothesis of the genetic continuity of the chromosomes, and also affords new data bearing on the problem of sex-production.

The studies of Mr. Payne, made especially on the genus *Galgulus* and on several genera of the reduvioid Hemiptera, have brought to light several new and interesting types of sexual differences of the chromosomes. All of them conform to the general principle, already established for other forms, that half the spermatozoa are male-producing and half female-producing; but the special modifications of the process are shown to be much more varied and extensive than was at first supposed, and give valuable data in regard to the manner in which the number of chromosomes changes from species to species. A brief paper on the phenomena in *Galgulus* has been published in the Biological Bulletin for April, 1908, and a full presentation of the results on all the forms studied is well advanced towards completion.

Mr. Morrill's work has been devoted to a comparison of the chromosomes in the oögenesis, fertilization and early stages of development of the egg with those seen in the spermatogenesis.

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